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ABSTRACT

This fourth annual yearbook of the Association for the Education of Teachers of Science presents eight articles relating to science teacher education. The articles include: a summary of science education and science teacher education from 1900 to 1975, a review of problems and innovations in preservice teacher education, a review of inservice science education, a look at the position of the science supervisor, a review of science education doctoral programs, a summary of science teacher education-related research, an examination of current important factors which may involve alternative science education methods in the future, and an overall review of the past, present, and future needs of science education. (SL)

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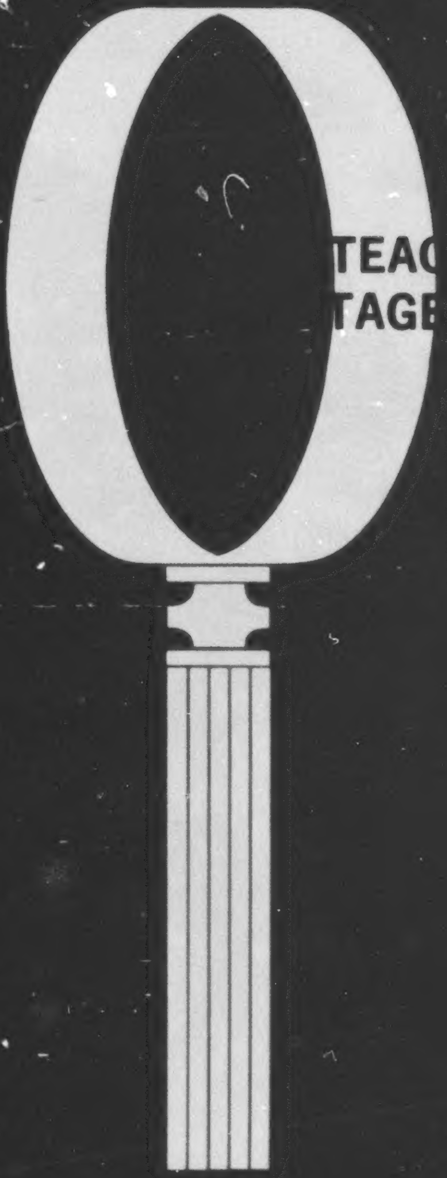

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1977 AETS YEARBOOK

SCIENCE TEACHER EDUCATION: VANTAGE POINT 1976

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ERIC/SMEAC and AETS are currently cooperating on a fourth publication. We invite your comments and suggestions on this series.

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PREFACE

This is the Fourth Annual Yearbook of the Association for the Education of Teachers of Science (AETS). It was written at the end of the 200th year of our country at a time when the recent fantastic growth of science education is at an end. A bicentennial steam locomotive drawn train is touring the country with memorabilia; our nation and the world are continually having crises (e.g., economic, environmental, energy); the "quality of life" is growing worse at what will soon be a frightening rate; we have for the first time a president that was not elected by the people; and, the most sacred of institutions, the National Science Foundation, has been attacked by Congress and the paying public. As a consequence, science educators are having to face the realities of a much larger and more complex world than was theirs even one year ago.

For science education, the next several years are critical to its healthy survival. Large-scale curriculum development projects, unlimited resources, and expansion are no longer possibilities. Behaving as a mature adaptive profession is vital to the well-being of science education. Yet, only fifteen years ago, science education was just beginning its contemporary rebirth. The profession in many ways is still an adolescent, yet, for its own survival, science education must address the issues facing it as a wise and well-seasoned profession.

As we approached the bicentennial anniversary of the United States, Jake Blankenship, President of AETS, the AETS Yearbook Committee and I wanted to use the Fourth Annual Yearbook to take inventory. We thought that we should summarize our recent successes in science education, take note of the resources and needs in science education today, and see if we could develop some glimpses of the future — some glimpses that might help science education in systematically planning for and constructively contributing to the future.

We knew that some areas of assessment were obvious. Preservice and inservice science teacher education and research came readily to mind. Two of the previous AETS yearbooks, A Review of Research on Teacher Behavior Relating to Science Education and Science Teacher Education 1974: Issues and Positions, have addressed these areas. However, we thought that these areas needed to be looked at again in light of the broader picture, the whole of education and the whole of our society. There were other areas that we suspected were being neglected, supervision being one. We also felt strongly that stopping with the present was no good. Somehow, we have to face the future and start planning in anticipation of the future.

With these goals and concerns in mind, we turned to the membership of AETS, the profession of science education, and asked some of our best to address the issues in the various identified "compartments" of science education. We asked our colleagues to summarize the past and present and to project about the future.

We chose well. The authors have come through with flying colors and in what for every one of them was an anguishing experience. Each author suffered and discovered. In most areas, our recent past is resplendent with accomplishments, although there are some woeful exceptions. With mixed emotions, I noted during the last year that each author, at some time, came to the saddening realization that our present is not ready for the future. Each author, as s/he worked, had difficulty in grasping the future, yet each gave it her/his best, providing for some interesting and insightful reading.

In Chapter 1, Realities of the Times in Science Teacher Education, Jim Barufaldi sets the stage by summarizing the growth and development of science education and science teacher education in the first 75 years of this century. He also points out some of the social, political and economic issues that we must face today, since science education is not an independent system, but rather a subsystem of education and of the larger society.

Gene Craven amplifies the recent historical, economic, and social issues in Chapter 2, Preservice Science Teacher Education. Gene discusses some of the problems with preservice teacher education and describes some recent innovative concepts such as competency-based education. He ends his chapter by describing several of the innovative preservice science teacher education programs that are presently in operation around the nation.

Alan Voelker, in writing Chapter 3, Inservice Science Teacher Education, had a difficult potpourri of ideas, practices and beliefs to grapple with. Inservice education is just beginning to have a conceptual base. Al proposes his own conceptual schema for organizing inservice teacher education around its "forms" and "functions." This chapter also includes descriptions of some promising practices in inservice teacher education, such as teacher centers, as well as suggestions for future directions.

Bill McIlwaine and Bob Ziegler had what initially looked like an easy task to write Chapter 4, Science Supervision: Form and Function. Writing this chapter turned out to be very difficult because it seems that we have not attended to supervision in any systematic way. Supervision appears to be one area with a promising future in terms of need and potential pay off for science education: teachers and students. Bill and Bob point out some promising practices but mainly develop a heavy indictment about our neglect and the consequences if we do not, in the near future, face the issues and potential of supervision.

Dave Butts was a logical person to explore the past, present and future of science education doctoral programs in Chapter 5, Doctoral Programs for Science Educators. Dave chaired the AETS committee that recently revised the doctoral guidelines and he has also served as doctoral advisor to many of today's science educators. In developing this chapter, Dave surveyed many of the present doctoral programs around the nation. He found what appear to be major discrepancies among present doctoral programs, the ideal future as reflected in the revised guidelines and future requirements as projected by today's doctoral program personnel.

Mary Budd Rowe is one of the leading teacher education researchers in the science education community and was the logical person to write Chapter 6, In Pursuit of Quality: Research on the Education of Teachers. Mary Budd ably summarizes much of the science teacher education-related research. In addition, she synthesizes the individual studies into a coherent set of statements about teacher education centered around two dimensions: quality and caring. Her synthesis of the literature is interesting with suggestions for research, rhetorical questions for the teacher educator and the raising of methodological and philosophical issues about teacher education.

In planning for this Yearbook, Jake and I wanted to be sure that the future was the main emphasis. This emphasis was not to be made by allowing the authors to write more pages about the future, but rather to encourage them to build their cases well, based on the past and the present, and then to extrapolate to the future. We also recognized that most of us in science education represent the mainstream of thought and, on future projections, were likely to be fairly conventional. However, one of the strengths of the science education profession is the richness and diversity of the minds of its members. So, we asked one of our potentially more divergent and most committed colleagues to attempt a "set breaking" chapter about the future. Chapter 7, Science, Society, and Education at the Crossroads: On Learning How to Make Love in a Liferaft by Dave Newton is the result. Dave also experienced a great deal of chewing and re-examining in writing his chapter. He had some things he wanted to say about science, society and schools, but pulling these ideas together in a way that would communicate without alienating was a challenge. His chapter ties together and articulates many of the social, political and economic factors alluded to in earlier chapters. The chapter is thought-provoking and includes many references for further reading that are not apt to be found on the mainstream science educator's bookshelf.

Synthesizing from all of these chapters and tying up the loose ends was the task for Howard Jones in Chapter 8, The Past, Present and Future of Science Education Before, During and After the Year of the Golden-Fleeced MACOS. Howie represents a rare perspective that made him unique for this task. He has spent this last year as a visiting staff member at the National Science Foundation as the Foundation has been under fire. Thus, Howie was able to bring the "Washington perspective" in addition to his science teacher education experiences and knowledge to the task. As with the other authors, he builds his case well and lays it on the line about the present and future of science education.

From the opening chapter to the last, this Yearbook represents a summary of many of our past accomplishments, our present dilemmas in science education, and some pressing concerns about the future. In Chapter 2, Gene Craven says:

> "In contrast to the 1960's, there appears [illegible] consensus today among science educators, academic professors, and science teachers as to the primary goal of science education for the next decade and beyond."

This theme is repeated through the chapters and, in concluding Chapter 8, Howard Jones summarizes by saying:

> "Our time for exploration in an infinite number of directions is past. An immediate goal for AETS and all of science education must be the identification of persuasive priorities. We can no longer afford the luxury of being everything to everyone."

In summary, I see the authors of this Yearbook as having exceeded the expectations of those of us who originally conceived it. If anything, their sense of urgency is even greater than ours. The future of science education is uncertain from our point of view. A different kind of movement is needed for the future. We cannot return to the big curriculum development days of the 1960's. After all is said, the question of how, or if, we will pull together and move proactively and thereby continue to be a leadership force is the bottom line.

A Personal Note

A personal acknowledgement of the many science educators who contributed of their time to make this Yearbook a quality product must be made. Fred Fox, the series editor, provided invaluable conceptual perspective and insight to me and the authors. Dave Ost and the members of his Yearbook Committee -- Michael Abraham, Bob James, Addison Lee, William Capie, Fred Fox -- were much appreciated for their very constructive reviews of the chapter drafts and assistance in planning the whole project. Thanks are also due Jake Blankenship, 1975-76 AETS President, who said, "This is what I would like," and then trusted us to do it. And last but not least, the chapter authors need to be recognized for the hard work and the quality work they did in the midst of their daily press.

Because there are science educators like these, the promise of the future of science education looks very good indeed.

Gene E. Hall, Editor

INTRODUCTION

The science education scene is a changing one. It always has been -- and always will be! Members of AETS not only recognize that change is occurring, but indeed, because of their activities, are contributing to the change. The rate of change, the only variable in this otherwise constant, seems to be accelerating. There is little doubt that the rate of change is the result of a complex mix of factors.

As an example of change, National Science Foundation funding of curriculum development has resulted in a diversity of science programs previously unknown. Without this support, the reluctance of the private sector of our society to invest in the expensive research and development activities necessary to produce "programs" rather than textbooks would have prevented some of the updating of content, teaching strategies, and the generation of learning options for schools and students that we have observed. Science as a process has received emphasis that has helped to bring a balance to the previously heavily product (fact/concept) oriented science courses. Funding for implementation by NSF has permitted school districts to begin experimenting with alternatives to the conventional programs. The "experimenting" stimulus has in many instances resulted in excitement among the teachers -- creating quests for more knowledge and skills with which to teach science more effectively. What has been, and will be, the effect of changes in funding patterns?

The "disaffection with science" observed during the first half of the decade of the 70's is an example of a rapidly changing attitude toward science. The "affection" stage may have peaked in 1969 with the ". . . giant leap for mankind." The effect of the "disaffection with science" may have already shown up in the 1973 National Assessment of Science. The total impact of the "disaffection" has not yet become apparent. Few, if any, would discount its influence on the rate of change of science education.

Many science educators are concerned about the direction science education has taken. Some express the thought that science education will follow the example of the railroads who got so busy playing trains that they forgot about transportation. What should be our focus? To which drumbeat do we, and/or should we, march?

The feeling has been strong on the part of some science educators that developing a perspective on the recent accomplishments and future directions of science education was needed. It was realized that an attempt to develop such a resource and guide would be an ambitious undertaking for an AETS Yearbook. The AETS President contacted the executive secretary for the National Society for the Study of Education (NSSE) and inquired whether there existed plans for a science education theme in an NSSE Yearbook in the near future. The response indicated that there were no plans to publish a "rethinking science education" type yearbook.

The AETS President and the Yearbook Editor received support and encouragement from the AETS Yearbook Editorial Board. Each chapter author was selected using a process that involved identification of prospective authors by the Editorial Board. The quality of this document speaks for the effectiveness of the process.

This Fourth AETS Yearbook is the product of authors whose professional commitments and scholarly activities enabled them to scrutinize science education as it was, is, and may become. This volume certainly has the potential for becoming the working document that was originally anticipated. I commend it to you.

Jacob W. Blankenship
AETS President, 1975-76

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CHAPTER 1

REALITIES OF THE TIMES IN SCIENCE TEACHER EDUCATION

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> The basic function of all education, even in the most traditional sense, is to increase the survival prospects of the group. If this function is fulfilled, the group survives. If not, it doesn't.*

The future of science teacher education depends upon understanding the many revolutionary changes that have occurred and that are presently evident in the social, economic, and political arenas of today's world. An important task for science educators is to examine how the pertinent issues from the past and present, resulting from societal changes, have influenced science teacher education. These issues and their effects upon science teacher education provide a set induction for the succeeding chapters of this yearbook.

Upon examination of the various issues and events in teacher education that affected the direction of science teacher education, certain realities from the past have been synthesized and presented. It is important to consider these realities in "futuring" about new directions for science teacher education.

In this synthesis, it is anticipated that the realities will demonstrate the interdependence of science education on the larger scene of our total society and will assist in planning for the future, thereby enabling science teacher education to take command of its own destiny.

The Need for Special Training for Science Teachers

During the first two decades of the Twentieth Century, changes in the economic, social, and political arenas were rapid. The revolutionary societal changes were the result of many interdependent factors. The age of the Industrial Revolution was indeed a revolution. Mechanization, initiated by the mass production of steel, expansion of the textile industry, demands for oil and by-products, production of electric power, utilization of the internal combustion engine, and production of automobiles, resulted in a tremendous spurt of industrial productivity and reached its peak for this period in 1916, during World War I. There was an unprecedented demand for more and more people to fill the skilled, semi-skilled, and unskilled jobs during this period of industrialization. In each of six separate years between 1905 and 1914 more than one million people immigrated to the United States. It was a time when immigrants were welcomed and encouraged to come to America. The country also witnessed a 30 percent increase in urbanization. The mass exodus from the rural areas to the urban, industrialized regions, supported the rationale of the nature study movement in science teaching that was prevalent at the time.

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*Neil Postman and Charles Weingartner. Teaching as a Subversive Activity. New York City, New York: Delacorte Press, P. 207, 1969.

By 1910, the majority of the states had enacted Compulsory School Attendance Laws. Between 1900 and 1920 the public school system witnessed a 39 percent increase in the total school population and a 60 percent increase in the number of public school teachers. By 1920, approximately 78 percent of school-age children, between the ages of five and seventeen, were enrolled in the schools. This increase was also stimulated by the enactment of the Federal Child Labor Law of 1916.

Before the turn of the century, the National Education Association was quite instrumental in influencing the educational system. Through the formation of the National Education Association's Committee of Ten and the accomplishments of this committee, various changes in secondary education occurred (34). The Committee supported the stabilization of science offerings in schools and emphasized laboratory work and other direct concrete experiences for secondary school students. A very significant event arose when this Committee recommended the need for special training for science teachers. By 1920 the rising importance of science and technology was evident. Educators were cognizant of the revolutionary changes occurring in society and the possible effects of these changes upon education. In addition, the public recognized science as a field of study.

Science curricula in the schools appeared to have reflected scientific and technological changes. High school courses in life sciences, general sciences, household chemistry, and various safety programs were in operation. The purpose of these courses was to enable students to become scientifically literate.

Such men as John Dewey rose to prominence during this time. Dewey contributed greatly to the field of education. His thoughts, works, and creative ideas were especially meaningful to those interested in science instruction. Terms and phrases such as inquiry, science as inquiry, learning by doing, promoted by Dewey, are very important philosophical underpinnings of science education to this day.

In 1918, the Seven Cardinal Principles provided a focus for the goals of education (18). The widely cited Principles -- health, command of fundamental processes, worthy home membership, effective citizenship, vocational efficiency, worthy use of leisure, and ethical character -- provided the frame of reference toward which all science teaching was expected to make contributions.

During these two decades, other changes within education were initiated, such as the Progressive Education Movement; nonetheless, when one considers the dramatic changes in scientific technology, society, and the economy, the changes that occurred in general education and science education were minor by comparison.

Paul DeHart Hurd has written that,

> . . . at the turn of the century, however, America began to move from an agrarian society to a scientific-technological society. Adjustments made in the science curricula reflected new technological developments but generally failed to reflect the advent of modern science. The impact of science on man's thinking, on social conditions, on economic development and on political action escaped widespread attention, even among highly educated non-scientists. In many ways the influence of science in shaping modern America is the unwritten history of the Twentieth Century (26:21).

The reality of this historic time was that changes in science teacher education were slow and evolutionary in nature. While curricula in the sciences may have attempted to reflect technological changes in science, they failed to reflect or keep pace with changes occurring in the other facets of society.

Changes in Science Curricula Were Not Only Anticipated but Encouraged by the Educational Community

During the twenty years following the close of World War I, the momentum of change that was initiated by the Industrial Revolution continued. The swift economic expansion of 1922-29, resulting from the tremendous increase in industrial productivity and an unprecedented surge in construction, provided a stimulating atmosphere for educators to rethink science education in this decade of scientific and technological development. The reports of the Committee on the Reorganization of Science in Secondary School of 1920 presented ways science instruction could contribute to the attainment of the Seven Cardinal Principles of secondary curriculum (10). This greatly influenced the refinement of curriculum throughout the decade. "Many scientists at this time expressed the opinion that the central purpose of education in science should be the development of an understanding of the nature of science, its methods, attitudes, and cultural impact" (24:51). Craig, in addition to supporting the cognitive facets of science education also stressed the affective dimensions: attitudes, interests, and appreciations (12).

In 1924 the American Association for the Advancement of Science, Committee on the Place of the Sciences in Education, addressed many problems of science teaching (9). The Committee debated the problem of science courses, and was quite critical of the science courses used in the training of prospective science teachers at the university. The Committee supported the notion that these courses were useful for the scientist but not suitable for training teachers. The Committee emphasized the need to train science teachers.

In 1928 the AAAS published a report, "On the Place of Science in Education," which criticized the training of science teachers (3). The Committee suggested that science courses for prospective science teachers should be organized to include the content of those courses that they will eventually teach.

The economic crash of 1929 and resulting depression years in America produced the expected public reactions against science, technology, and the educational practices during times of economic crisis. The loss of 132 billion dollars in national income was astounding. People were very much aware of science and implications concerning technology. They questioned the purposes of science in general education, and needless to say, the cost of teaching science. The public placed much of the responsibility for this devastating economic period on the impact of scientific and technological development. The common opinion was that science was responsible for the unemployment that resulted in America from the mechanization in farming and automation in the factories. Fifteen million people were unemployed during 1930-33.

In 1930, 56 percent of the population resided in urban areas. Eighty percent of the school age population was enrolled in schools and this figure continued to increase. In 1930, 880,000 teachers were teaching in public schools, a 29 percent increase from 1920. The prevalent economic and social crises, resulting in a great period of questioning of science, forced education to focus upon the individual student's welfare: social, economic and health.

In 1932 A Program for Teaching Science, sponsored by the National Society for the Study of Education, was developed (37). The report that resulted advocated the selection of science content on personal and social criteria, reflecting the educational thinking that was progressing in that direction. The Report supported the development of a comprehensive program of science teaching, grades one through twelve, based on a number of selected scientific principles or generalizations instead of aims or objectives.

The report of the Committee on the Function of Science in General Education, sponsored by the Progressive Education Association of 1932, also supported the educational thinking of this time.

> Some of the characteristic recommendations of the Committee were: 1) the democratic way of life constitutes the goals of education; 2) the concept of science teaching exists within the context of general education rather than contributing to it; 3) the need to develop the personal-social characteristics of students, as well as intellectual interests; 4) courses should be organized around large units of human experience, rather than the logic of the subject; 5) the personal-social needs of students should be the point of departure in curriculum construction; 6) functional or operative science instruction is sought rather than the memorization of masses of facts; 7) results of evaluation should be used in the guidance of students toward the goals of science teaching (24:66).

Caldwell, in attempting to project the next ten years in science education, emphasized that important changes in the training of science teachers were imperative. He believed that the changes must relate to an increasing science scholarship, to an increasing professional efficiency, and to the ability to demonsrate to administrative and financial agencies the kinds of informed support required for effective work in science (11).

Johnson believed that the methodology in the teaching of science was overly stressed (27). He recommended that the prospective science teacher should have a professional major with a minor and some "slight acquaintances" with the methods of research. Reflecting the economic situation of this period, he stated that "if we want our graduates in science from our Teachers Colleges to secure jobs, we had better have them well-grounded academically in one or two fields rather than be a jack-of-all-trades in many fields" (27:6).

The reality of this historic time was that changes in science curricula were not only anticipated but encouraged by the educational community. Through the work of many committees, the curricula were refined, reflecting changes in the social, economic, and political arenas. Nonetheless, only minor changes occurred in the preparation of science teachers.

Recommendations to Improve the Education of Science Teachers

The entry of America into World War II brought large-scale mobilization of manpower and resources, with economic activity making great strides. In 1940, 57 percent of the population resided in urban areas, increasing slightly from the 1930's. The percentage of school age population enrolled in schools remained relatively stable from the previous decade. A slight increase in the number of teachers in public schools occurred; nonetheless, the increase was slowly eroded by the manpower demands of the war and the movement of teachers into higher paying positions in industry.

The advent of World War II and the birth of the "atomic age" resulting from the first test of the atomic bomb in 1945 stimulated a great period of questioning, not only of present science curricula and current science teacher education programs but also of general education. Minor changes in science curricula occurred, reflecting the demands of a nation at war. New courses, such as aviation and electronics, were added to the secondary school curriculum. Consumer education, stressing the practical applications of scientific technology to basic problems of daily living, was thought to be a guiding framework for courses (24:74). In a report of the American Council of Science Teachers, Science Teaching for Better Living, the addition of consumer education, safety, and conservation to the curriculum was recommended (5).

The technical manpower crisis due to World War II produced many problems. The question, is science for the scientist or for everyone, was debated. The demand for special training in technical skills encouraged the development of vocational training. The preparation of science teachers was vigorously criticized. Most reports characterized the science teachers as being poorly prepared in their respective subjects (29). This criticism, historically, has persisted throughout the decades.

Throughout this period many committees and individuals suggested specific recommendations to improve the education of science teachers. The report of the Harvard University Committee on General Education emphasized science as a field of study, giving importance to scientific thinking (23). The science teacher was viewed as someone with a strong background in both science and the liberal arts.

In 1947 the AAAS Cooperative Committee on the Teaching of Science and Mathematics published an analysis as part of the Steelman Report, Science and Public Policy (43). Recommendations germane to science teacher education were:

- the establishment and systematic organization of inservice teacher training programs, for both elementary and secondary teachers;
- the need to make Federal funds available to supplement low wages in teaching;
- the initiation of studies by teacher's colleges to determine appropriate science courses for prospective elementary school science teachers;
- the inclusion of laboratory work and field work for prospective elementary science teachers;
- the need for specifically planned professional programs for prospective secondary science teachers;
- the offering of graduate work in science that would be relevant to the teachers;
- the certification of teachers granted on the basis of broad preparation in general science to teach general science in junior high schools;
- the establishment of certification policies in subjects within the broad area of science and mathematics (43: Appendix 2).

Science Education in American Schools, a publication of the National Society for the Study of Education, presents many suggestions concerning the philosophy of science teaching, methods of science instruction, and curriculum (35). Social implications of science and laboratory techniques in secondary school science classes were emphasized.

The functional objectives for science teaching, conceived as directions of growth were:

- functional information;
- functional concepts;
- functional understanding of principles;
- instrumental skills;
- problem solving skills;
- attitudes;
- appreciations;
- interests (35:26).

The report of the AAAS Cooperative Committee on the Effectiveness of Science Teaching in 1948 recommended that the teachers of science need to be trained in the broad areas of science rather than in the specialized areas (28). In addition, the Committee recommended development of a curriculum appropriate for the preparation of teachers in science.

The Dawn of Contemporary Science Teacher Education

The 1950's may be characterized as both the "dawn of the space age" and the "dawn of contemporary science education." Many individuals noted discrepancies between the desired preparation of science teachers and the actual preparation of those presently teaching. Professional societies and organizations of scientists, educators, industries, and foundations supported and stimulated curriculum studies and teacher education programs. The National Science Foundation strongly supported the many facets of science teacher education. This decade, therefore, marked the beginning of increased federal intervention in science education.

During this decade it became quite apparent that the scientific revolution, resulting from the accelerated growth of science and technology following the close of World War II, made the understanding of science imperative in the education of all people.

In 1955, the White House Conference on Education focused attention on educational goals as well as needs, teacher training and recruitment, and school financing. The proposition that the federal government should increase its fundamental participation in public education was approved.

The launching of Sputnik I, November 3, 1957, by the USSR, enhanced a series of national concerns about the place of science in education and the preparation of science teachers. A week later, the United States Office of Education released a two-year study of the Soviet educational system, revealing vast strides being made in secondary and technical education in the USSR, stressing science subjects. These reports coupled with the belief that "America was losing the space battle" stimulated the acceptance of greater federal intervention in financing public education.

In 1958, the passing of the National Defense Education Act provided a 295 million dollar loan fund for college students, with a reduction of the loan if the student later taught in an elementary or a secondary school for five years after graduation. In addition, 280 million dollars were voted for grants to state schools for facilities in science or modern foreign languages. A matching grant component was also included in the Act (44).

By the late 1950's, 70 percent of the population resided in urban-suburban areas. The school population increased 42 percent since 1940. Even though an increase of 54 percent in teachers was noted since 1940, the teacher supply in the sciences was dangerously low. In addition, people were cognizant of the notion that a shortage of qualified science teachers was affecting the economy. The supply of teachers was short of the annual need, which was estimated, in

1961, between eight and ten thousand teachers per year for grades nine through twelve.

Throughout the decade beginning with 1950, the number of college graduates with science majors who desired to teach dropped each year, while enrollments in science increased. At no time during the 1950-60 period was it possible to fill but a fraction of the teaching vacancies in science with qualified teachers (24:110).

The reports of numerous committees and organizations emphasized both the need for improving science curricula and the need for improvement of science teacher education. Educators were quite concerned with what the prospective teacher needed to learn; therefore, recommendations for preparing teachers were quite specific in terms of the nature of courses and the amount of study. Watson believed that it was:

> . . . time we considered teaching as a socially important career involving thousands of college graduates and began planning programs specifically for their preparation, rather than insisting upon the time-hallowed pattern of majors and minors intended to prepare students for admission to graduate schools in a narrow field of study (47: 192-193).

This conviction is reflected in a report by the National Association of State Directors of Teacher Education and Certification in cooperation with the American Assocation for the Advancement of Science (1). The report included the following eight guidelines:

I. The program should include a thorough, college-level study of the aspects of the subjects that are included in the high school curriculum.
II. The program should take into account the sequential nature of the subject to be taught, and in particular should provide the prospective teacher with an understanding of the aspects of the subject which his students will meet in subsequent courses.
III. The program should include a major in the subject to be taught, with courses chosen for their relevance to the high school curriculum.
IV. The major should include sufficient preparation for the later pursuit of graduate work in one of the sciences or in mathematics.
V. The fifth year program should emphasize courses in the subject to be taught.
VI. The program should include work in areas related to the subject to be taught.
VII. The program should include preparation in the methods especially appropriate to the subject to be taught.
VIII. The program should take into account the recommendations for curriculum improvements currently being made by various national groups.

The reality of this historic time was that changes in science curricula, supported by federal intervention in public education, were occurring rapidly, giving rise to the "dawn of contemporary science teacher education programs." Through the work of many educational committees, the curricula were redefined reflecting changes in the social, economic, and political arenas; nonetheless, changes in science teacher education programs were only anticipated, not operationalized.

Major Reform in Science Curricula

During the decade of the 1960's, an unprecedented growth in federal support for education occurred. Between 1963 and 1967 federal funds appropriated for education increased from 5.4 billion to 12.2 billion dollars. Legislative measures, such as the Vocational Education Act - 1963, Elementary and Secondary Education Act - 1965, Higher Education Act - 1965, and Higher Education Act Amendments - 1968, were passed. The Assistance to Education, granting 1.3 billion dollars to school districts on the basis of the number of needy children, was the first large scale program to aid elementary and secondary schools. The Higher Education Act of 1965 provided the first federal scholarships for general college undergraduates. Title IV of the National Defense Education Act (NDEA) authorized 1,000 grants in 1959 and an additional 1,500 grants in each of the succeeding five years to make graduate study financially possible for qualified students. Title III of the NDEA provided instructional materials for science and mathematics. Seventy-three percent of the funds under Title III were for science only (44:33). Between 1956 and 1962 more than 122 million dollars in federal funds were spent for the improvement of science education (33).

The social, economic, and political forces of the 1950's and 1960's brought about the first major reform in science curricula. ". . . the emerging social, economic, political and technological developments intensified the concerns about the science curriculum" (24:235). This revolutionary reform movement supported and encouraged by the National Science Foundation (NSF) was rather unique in American education. As Dede and Hardin summarized:

> First, it attempted to replace the present curriculum rather than revise it. Second, it employed leadership from professional scientists in universities rather than from educators. Third, it used money from foundations and federal grants rather than the usual state and local sources of funding (20:486).

The reform supported the development of materials emphasizing scientific inquiry within a discipline-centered curriculum. Programs such as the Physical Science Study Committee, the Biological Sciences Curriculum Study, the Chemical Bond Approach, Chemical Educational Materials Study, the American Association for the Advancement of Science: Science - A Process Approach, the Elementary Science Study, and the Intermediate Science Curriculum Study were part of the new science programs supported by NSF.

These programs demanded the upgrading of teacher competency for successful teaching of the courses. NSF provided support for teacher training, improvement in science instructional materials, assistance to schools in implementing curriculum reform, and activities for high-ability students. An extensive program of Academic Year Institutes, Inservice Institutes, Summer Institutes, Training Programs for High-Ability Secondary Students, Cooperative College-Science Programs for School System Improvement, and Holiday Science Lectures financed by NSF was an intrinsic part of most of the new curriculum materials. The NSF-sponsored summer and academic year institutes did much to upgrade the graduate level programs in science teacher education. In conjunction with this movement science education centers were established at many universities and colleges offering graduate degrees in science education.

Many employment opportunities were available for these graduates in national and state agencies, at universities and colleges, and in various capacities in public school systems. Historically, the late 1950's and early 1960's ushered in the "era of science teacher education." Science teacher education received extensive financial support, curricula innovations were rapidly occurring, and most importantly, attention was focused upon the need for improved preservice and inservice training of teachers.

In the 1960's, changes in the social and political arenas were occurring rapidly. The United States' involvement in Southeast Asia, campus demonstrations, turmoil in urban areas, the Civil Rights movement, assassinations of national political leaders, and protest marches resulted in new criticisms of the American educational system and demanded a "rethinking of national priorities." Critics demanded "relevancy" in the curriculum. Students wanted a curriculum that prepared them to deal with important social issues.

> Today's students want to see how science relates to themselves, their environment, society and the future of mankind. Students want a science course to be both pragmatic and value oriented. They want to see emphasis on drugs, ecology, respect for the environment, responsibility of people and institutions and something of 'relevance' as well as some ideas on how to do something about these problems (22:5).

Many shared the belief that during the "era of science teacher education" little change occurred in the education of teachers.

> . . . the preservice education of science and mathematics teachers was not substantially changed during this time. Programs for the preparation of science and mathematics teachers have typically been derived from the existing school curriculum. As a result, teachers are prepared to teach what is already being questioned in the light of current educational insights and research. Entering teachers are often tradition-bound from the onset of their careers and too often find it difficult to adjust to new educational demands (2:1).

The urgent need for new guidelines in science teacher education was acknowledged with the publication of Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics (2) and Preservice Science Education of Elementary School Teachers (4).

Various guidelines of the aforementioned publications emphasized the significance of the humanistic movement in science teacher education of the 1970's.

> Guideline I - Teacher education programs should provide experiences that foster continuous growth in those human qualities of the teacher that will enhance learning by his students.
> Guideline VIII - The institution should insure that the teacher possesses skills required for effective human relations with children in the classroom by carefully and continually screening candidates for the teacher education program and providing experiences in which students develop the desired behaviors (2:5, 28).
>
> Guideline IX - Experiences in schools and in a community should be provided to develop a sensitivity toward, and an appreciation for, the school as a part of the community and as a democratic institution, and for individuals in the community (4:31).

The reality of this time was that changes in the social, economic, and political arenas stimulated the development, dissemination, and the implementation of innovative science curricular programs, demanding science educators rethink existing science teacher education programs. These changes, coupled with a general disenchantment with existing teacher education programs, provided the educational atmosphere in the late 1960's and 1970's that led to the generation and operationalization of innovative models for science teacher education programs.

Revitalization of Science Teacher Education Programs

As the 1960's drew to a close a pervasive distrust of institutions existed among the public in general, most distinctly expressed in the movement against the United States' involvement in Southeast Asia. There was a growing dissatisfaction with the results of the unprecedented expenditures for education with few observable changes. This dissatisfaction resulted in the defeat of numerous bond issues and levies proposed for education. This change in attitude from the early 1960's affected decisions of state legislators to hold members of the educational community accountable for the outcomes of their systems. The educational community also came under much criticism concerning the competence of teacher education graduates. The development of competency-based teacher education was in part an attempt to satisfy the demand for accountability.

Historically, science teacher education was affected by changes in the political, social, and economic conditions in society and eventually responded to these only after changes had already occurred in the other aspects of educational endeavor. For the first time a contemporary issue, accountability, provoked an immediate response from many teacher preparation institutions with the increased interest in performance/competency based teacher education programs. This immediate response to change by those concerned with teacher education provided the impetus for the revitalization of science teacher preparation programs and the generation of numerous innovative models for the education of science teachers.

The New Elementary Program - University of Florida (40), An Integrated Science Program for Preservice Elementary Teachers - Purdue University (36), A College School Cooperative Science Teacher Education Program - Richmond College of the City University of New York (7), The University of Iowa model (32), Project Assist - University of Iowa (42), and the Cooperative Teacher Education Program - University of Illinois (39) are some of the innovative models presently in operation.

In addition, science educators are beginning to examine other existing teacher education models (45). One example is the United States Office of Education - Teacher Corps project, established in 1966 as a training program for teachers of the disadvantaged (41:321). Others are considering alternate approaches as evidenced in the Portal School Program, a cooperative venture developed by the American Federation of Teachers, The Philadelphia Public Schools, Temple University, and the school community (35:41). The Emory University Program (38), the Teachers Training Teachers program in Florida (46), and the numerous competency-based teacher education programs found throughout our country are also receiving attention from the science education community.

Most of the models may be characterized as supporting:

- a shift from the dominant role of university personnel with on-campus teacher education programs to a field-based effort using supportive personnel from the public schools.
- a greater cooperative venture and shared responsibility for teacher education among university and public school personnel.
- the opportunity for prospective teachers to become involved with elementary and secondary students early in their university program.
- the humanistic movement in science education.

Earlier it was noted that, during the first two decades of the Twentieth Century, curricula in the sciences attempted to reflect technological changes in science but failed to keep pace with changes that occurred in other aspects of society. Presently, both external and internal forces such as world urbanization, the energy crisis, an inflationary recession, the knowledge explosion, world wide starvation, and the proliferation of mass media are initiating many revolutionary changes in society. Do the new "revitalized" approaches to teacher education possess sufficient flexibility to adapt quickly to the anticipated societal changes? Do the programs, practices, and research in science education possess the necessary elements to serve as agents of change?

Hurd has stated that a majority of the teacher education programs of the 1970's are obsolete because they are designed to teach the science of the 1960's and there is little attention to on-going cultural changes and emerging science curricula (25).

Do the programs, practices, and research in science education possess a degree of sensitivity to cultural change? Do they possess the necessary elements to compensate for the many predicted and unanticipated changes in culture?

The National Board of Graduate Education has suggested the following eight principal trends in the future affecting graduate education:

1. A steady reduction in demand for new Ph.D.'s to serve as college and university faculty members through the 1980's.
2. A reduced rate of growth of R & D expenditures relative to that of the 1960s, and hence reduced growth rates of demand for new Ph.D.'s in such activities (there will undoubtedly be specific research areas, however, that grow much faster than the average).
3. A substantial supply adjustment on the part of students and universities that will reduce the number of new Ph.D.'s awarded well below the number projected on the basis of past trends; in many fields, however, the supply of new doctorates will exceed the demand from traditional, discipline-related sources.
4. A continuing decline in the total amount of financial support available to full-time graduate students, thereby increasing the relative importance of loans and self-support.
5. Some increased enrollment demand by "nontraditional" graduate students, e.g., older students, part-time students, nonresidential students, women returning after child-rearing, and nondegree students.
6. An increase in the number of women and minority students seeking graduate education.
7. Continued focus on accountability, including program evaluation, cost analysis, and other measures of program performance.

8. No large new programs to support graduate education, barring a major intellectual breakthrough in some discipline or a substantial shift in national priorities (6:1-2).

Are the futurists in science education considering these trends in establishing guidelines for science education graduate programs? The Board also suggested the need for diverse opportunities for the nontraditional forms of graduate education, serving nontraditional graduate students. Will science education graduate programs evolve so that they will not only acknowledge the projected trends but also compensate for the diversity so evident in them?

Do the programs, practices, and research in science education possess the flexibility to respond to changes in attitudes toward education reflected in such realities as reduced university budgets, lack of financial support for science education by NSF, and criticisms of the educational community regarding the competence of teachers?

The Education Professions Development Act of the 1960's was aimed at attracting and qualifying teachers to meet critical teacher shortages (41:321). Presently we are encountering an over-supply of teachers. As a result, fewer undergraduates in our colleges and universities are enrolling in teacher education programs. In a recent survey conducted at the University of California at Los Angeles it was found that the percentage of new college freshmen planning to become teachers was the lowest it has been in ten years. Only 6.5 percent of this year's freshmen are planning to become teachers, compared to 8.2 percent one year ago and 21.7 percent in 1966 (21). Do the programs, practices, and research in science education possess the flexibility to respond to this reality?

Some individuals currently employed in the teaching profession are finding their positions eliminated as school systems encounter financial difficulty. During the past two years in New York City, 12 percent of the instructional staff has been cut, including the elimination of 8,138 teachers' jobs (19). Curtailment of services such as guidance, counseling, tutorial, and remedial help has occurred. This reality was clearly reflected in the headline of a story in The New York Times, "Cutback Here Saps Morale: Future Bleak," which included the following assessment: "Teacher morale is generally at a low ebb. Younger teachers are worried about their jobs; older teachers are worried about their pensions" (19:13). Can science education look beyond itself to the larger, more global picture?

In the two decades following World War I, the science curricula were refined, reflecting changes in the social, economic, and political arenas; however, a serious lag occurred between programs for science teacher education and curriculum development. The gap between the implementation of innovations in science curricula and teacher education appears to be narrowing with the revitalization of teacher education models; nevertheless, we must be cognizant of further revitalization of curricula in elementary, secondary, and college science programs during the 1970's. The emphasis on presenting science within a multidisciplinary context is evident in programs such as the BSCS -

Elementary School Sciences Program (14:3), Interdisciplinary Approaches to Chemistry (31:297), the Unified Science and Mathematics for Elementary Schools (31:387), the BSCS - Human Sciences Program (17), and the BSCS environmental module, Investigating Your Environment (16:3-4). The BSCS - Collegiate Minicourse Program contains clusters of modules which emphasize the multidisciplinary nature of biology (13).

Modularization, individualization, management systems, minicourses, self-paced, and instructional pathways are inseparable terms which are very much part of the new generation of curricula reforms.

The publication of the Science Curriculum Improvement Study (SCIS) - Beginnings program (31:364) and the development of the BSCS - Elementary School Sciences Program, Level R-Readiness (14:11), are indications of a renewed interest in providing a comprehensive series of science experiences for young children.

Special education students are also being provided with educationally and scientifically sound materials from the SCIS - Adapting Science Materials for the Blind (30), the BSCS - Me Now and Me and My Environment (15).

With the surge of present curricular reforms, one must ask, do the programs, practices, and research in science education possess sufficient sensitivity to enable the occurrence of simultaneous evolution of curriculum development and innovative teacher education programs?

Many educators have been cognizant of the need for greater involvement of teachers in innovative curriculum development. "The program (teacher education) should take into account the recommendations for curriculum improvements currently being made by various national groups" (47:193).

> Prospective teachers' involvement in innovative curriculum development should be a vital part of teacher training programs. It is considered to be probably the best place for constant development of instructional materials for new science curricula. An expected result: evolving of the curriculum in conjunction with teacher development (48:99).

The need for such involvement of teachers in curriculum development may be met by incorporating various components from the numerous Teacher Center models with a science teacher preparation program. Teacher Centers (8:44-61) such as those at the University of Houston and the University of Texas at El Paso show promise in proving the atmosphere conducive to the unique involvement of inservice and preservice teachers in curriculum development.

The seeds of hope for the future in science teacher education have been sown. We are presently cognizant of possible educational ramifications of the conditions in the social, economic, and political arenas and we are beginning to consider these possibilities in our planning.

Will the futurists who are involved with research in science education, inservice and preservice education, supervision and doctoral programs, while considering the realities of the times and present trends, provide the necessary guidance to enable those of us responsible for science teacher education to take command of our destiny?

In succeeding chapters, the authors will explore these and many other questions confronting teacher education in the sciences.

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CHAPTER 2

PRESERVICE SCIENCE TEACHER EDUCATION

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As never before, programs for the preservice education of science teachers are faced with critical examination. The school-age population is becoming smaller each year, a trend that is expected to continue for at least ten years before leveling off. A National Center for Educational Statistics report forecasts a 13 percent decrease in public secondary school enrollments between 1973 and 1983 (28). In the 1970's, enrollments in science classes have decreased as many secondary school students have found science to be less appealing than did their counterparts of the 1960's. The demand for new science teachers has dropped rather drastically while teacher education programs designed to meet the post World War II and post Sputnik shortages of science teachers continue to add graduates to the present surplus of certified teachers. This situation provides an opportunity to shift from an emphasis on numbers to an emphasis on quality in the preparation of teachers.

While programs for the preservice preparation of science teachers are typically designed for the existing discipline-centered curricula, the relevance of these curricula is being questioned. Nearly two decades of unprecedented public support of science and science education has been replaced by other priorities in response to world-wide population growth, energy and materials shortages, population of the environment, inflationary recession, and growing social tensions resulting, in part, from a widening gap in economic conditions between the affluent industrialized nations and the vastly overpopulated nations having extremely limited potential for economic development.

New directions for the education of teachers are being debated in the public press, state legislatures, and professional literature. There is consensus that the schools must better meet the educational needs of the individual student and that a discrepancy may now exist between the typical outcomes of secondary school science teaching and the most pressing needs of both the student and society. Public demands for educational accountability and requirements of certifying agencies that both high school graduation and teacher education programs be performance or competency based contribute to the necessity of rethinking existing programs for the preservice education of science teachers. Added stimulus comes from both beginning and veteran teachers who experience difficulties in adjusting to "new" professional demands, including the development of "more relevant" curricula, personalizing instruction, and assessing student attainment of non-subject matter goals.

Teacher education is a persistent problem. Whether the issue be teaching science as inquiry, developing "more relevant" curricula, more humanistic science teaching, personalization of instruction, developing scientific literacy, or competency based science education, the question that must eventually be answered is "How do we prepare the teachers to do these things?"

In this chapter, the status of the preservice training of science teachers will be described further and several major forces directing teacher education will be considered. Literature-based criticisms of conventional preservice programs will be reviewed. The concepts of teacher competence and competency based teacher education (CBTE) will be examined. Several current efforts to improve the preservice education of science teachers will be described. The chapter is concluded with some statements concerning science teacher education for the future, based upon promising aspects of some of today's particularly innovative programs.

FORCES REDIRECTING SCIENCE TEACHER EDUCATION

American science education has a long record of responding to social needs. As priorities change, "new" competencies are required of teachers in order to attain "new" goals of science instruction.

In the first decade of the twentieth century, civic biology was introduced into the schools to help solve the problem of poor health and disease resulting from people from many nations migrating into American schools with rapidly increasing enrollements. General science and general biology, both designed for the general education and orientation to science of all students, meant meeting the entire range of backgrounds, abilities, and interests of American youth. As was mentioned in the first chapter, John Dewey's problem-solving approach to education and its interpretation via the Progressive Education movement was followed by an emphasis on consumer science brought on by the great depression of the 1930's.

World War II effected an emphasis on the products of science-based technology such as plastics, DDT, jet engines, radar and television, and atomic energy (10). This was superseded by the conceptual scheme-structure of the discipline-process of science series of "teacher-proof" curriculum improvement projects of the 1960's which dominated science education for more than a decade. Throughout this era, Jerome Bruner's Process of Education, an outgrowth of the Woods Hole Conference of concerned scientists, and Theory Into Action, a publication resulting from an NSTA sponsored conference on science curriculum development had a definite impact on both curriculum development projects and programs to prepare teachers to use these materials.

In the late 1960's, domestic social problems and Viet Nam-related unrest culminated in an increasingly negative popular reaction to science in response to the use of science-based technology in warfare and a resulting deterioration of the environment. The current professional literature is calling for increased humanism in teaching (33, 35), an environmental consciousness, and curriculum-proof science teachers (36) who tailor their courses to the abilities, needs, and interests of their students.

Forces and factors, such as those that will now be examined, make demands upon science teachers that can be met only by revised and carefully designed programs for their preparation.

Economic Conditions

Economic factors not only affect the number of students preparing to teach science and the probability that they will be employed but could have a definite positive impact on the quality of training that is provided. During the post war era of teacher shortages, the National Defense Education Act provided financial inducements for college and university students to enter and remain in teaching. Colleges and universities receiving National Science Foundation grants for curriculum development or for the inservice training of science teachers through summer and academic year institutes, or both, typically upgraded their facilities, instructional materials, faculties, and programs for the preservice preparation of science teachers. Many university scientists demonstrated a high regard for precollege science teaching by helping develop improved curriculum materials and in providing college science courses designed to meet the needs of teachers using the "new" curricula. The net result was not only an increase in the number of teachers entering the profession but also an upgrading of their preparation in science and specific training to teach modern science courses.

Now, federal and private funds are not as readily available for the development of science curricula, implementation of curriculum materials developed by NSF funded projects, or teacher training. A predicted oversupply of science teachers and increased competition for the jobs that do exist may account for recent drops in enrollments in some programs for the preservice training of science teachers. A reduced enrollment can have a positive side effect IF teacher preparation institutions can rise to the challenge of redesigning the resulting more manageable, smaller enrollment programs to better provide the prospective science teacher with increasingly sophisticated knowledge, values, and skills necessary to interact effectively with the students that he is preparing to teach. Unfortunately, smaller enrollments are typically accompanied by a cutback in funds. This usually means fewer faculty, a reduction in the number of courses that can be offered, and fewer opportunities for released time for the time-consuming and often costly process of developing "new," innovative teacher preparation programs.

Teacher Certification

Changes in criteria for the initial certification of science teachers by state education agencies precipitate changes in programs for the preservice education of science teachers. While some state certification agencies specify the completion of specific courses in a teacher preparation institution, a majority require completion of a minimal number of hours in specified areas of study; general education, professional education, the teaching field, and electives. More commonly, completion of an approved program in science teacher education at a state accredited institution meets the requirement for initial certification.

Recently, competency based teacher certification has been legislated in several states. Teacher education institutions are required to identify, in behavioral terms, the competencies to be achieved by the prospective science teacher, design programs to develop these competencies, and attest to their attainment by the candidate for certification (17, 29, 37). This controversial approach to teacher certification has had a definite impact on teacher preparation institutions as they have struggled, often with short timelines, to change their programs to conform to "new" competency based rules for certification. Gage and Winne (17) state that few movements in teacher education have received such vigorous attention so quickly. The concept of competence of science teachers will be considered in more depth later in this chapter.

Changes in Philosophy and Psychology of Learning

The prevailing philosophy and widely accepted goals of science education have definite implications for teacher education programs. Progressive Education programs of the 1930's and 1940's, for example, often stressed human development, psychology of learning, and methodology at the expense of academic preparation in the discipline to be taught. This situation was reversed dramatically during the curriculum improvement period of the 1960's when academic rigor, in-depth preparation in the discipline, and scientific inquiry were stressed, sometimes at the expense of a variety of methodologies and psychological and social foundations of education. Recently, the goal of many secondary science programs appears to have changed to "making science relevant" through mini-courses, the content of which typically depends upon the background and interests of the teacher. Individualization of instruction and integrated studies that deal with social issues and problems are becoming more common components of the science program in many schools. As the goals of science education change, teachers must be prepared who possess "new" knowledge, pedagogical skills and values and attitudes necessary to attain these goals.

The National Scene

National priorities change, making new demands upon science teachers. During the 1930's the nation's priority was on the solution of social problems resulting from the world-wide depression that followed World War I. International tensions that resulted in World War II made the winning of that war the overriding priority of the 1940's. In the 1950's priority was given to winning the Cold War, an effort that called for increased scientific and technological manpower. In the schools, priority was given to the preparation of an adequate number of teachers to meet the demands of the post-war school population boom. In science education, priority was given to upgrading the science background of inservice teachers and preparing large numbers of undergraduates for initial certification. During the decade of the 1960's, scientists and science educators were almost unanimous in the priority given to the development of up-to-date curriculum materials emphasizing conceptual schemes, the structure-of-the-discipline, and instruction that emphasized the processes of science and scientific inquiry. As a nation, we had been committed to "landing a man on the moon by the end of the decade," a goal that was achieved with remarkable success. Late in the 1960's and early in the 1970's the nation became preoccupied with an unpopular and unsuccessful military commitment in Southeast Asia. Concurrently, a social consciousness developed concerning the environment and damages it was undergoing as a result of the misuse of science-related technologies. More recently, a world wide energy problem has become evident. It is clear that our style of life will have to become more Spartan well before the end of the century. While the necessity of resolving the energy problem is being reluctantly accepted, it is by no means clear that we have, as a nation, committed ourselves to energy independence, if indeed this is possible.

It is apparent that the highest order of national priority should be that of establishing clear priorities for the remainder of this century. With national priorities established, the goals of the schools could be determined, appropriate science curricula designed, and teachers prepared to enable the student, the school, and the science teacher to attain these goals. In contrast to the 1960's, there appears to be no consensus today among science educators, academic professors, and science teachers as to the primary goal of science education for the next decade and beyond. This lack of consensus can only contribute to the inadequacy of programs for the preservice education of science teachers.

Societal Criticisms of Science Teaching

Responsible criticisms of science teaching at all levels and of programs for the preparation of science teachers is a strong agent for change. Following World War II, for example, the schools in general and science education in particular came under sharp attack by dissatisified parents, journalists, college and university professors, and a famous admiral (43). Extensive testing of military inductees had revealed an appalling lack of scientific literacy by recent high school graduates. American science education was frequently compared unfavorably to that of European countries. Studies revealed that many science teachers had very limited preparation in science and that this preparation was often out of date. Academic professors and scientific societies responded by assuming new responsibilities for the preparation of science teachers and the development of improved science curriculum materials for use in elementary and secondary schools. Generous funding became available through the National Science Foundation to support science curriculum improvement projects and the training of teachers to use these materials as intended by the developers. Programs for the preservice preparation of science teachers typically included a strong preparation in science, with methods courses stressing the new curriculum materials and an inquiry or process approach to science teaching.

In the late 1960's, riots in protest of deteriorating living conditions in the large cities and of the American involvement in Southeast Asia resulted in a new wave of criticisms of the schools and charges that science education was not only irrelevant but that its applications were detrimental to the world's delicate ecological balance. There were charges that science education was meeting neither the personal needs of a majority of the secondary school students nor preparing them to deal with important social problems. Fewer high school and college students elected to study science. In an effort to reverse this trend, mini-courses were frequently added to the science program in an attempt to make science "more relevant." Teacher education programs, including those at the author's institution, have responded by placing less emphasis on the preparation of students to teach Project Physics, BSCS biology, CHEM Study or science as inquiry and more emphasis on student-teacher interactions, individualizing instruction, and the development of educational modules or mini-courses.

Because of the magnitude of the impact of responsible critics on programs for the preparation of teachers, several criticisms of conventional science teacher education programs by teacher educators writing in the professional journals and other responsible critics will be examined.

CRITICISMS OF CONVENTIONAL SCIENCE TEACHER EDUCATION PROGRAMS

Beginning Teachers are Inadequately Prepared in Science to be Effective Science Teachers.

Lack of subject matter competence is a persistent problem in science teacher education. School administrators, cooperating teachers, science educators, college and university scientists, scientific societies, and the science teacher candidates all agree upon the importance of competence in the subject to be taught and the fact that there is need for better subject matter preparation. For certification purposes, competency is usually inferred from titles of courses, number and distribution of university credits completed, and grades earned.

The prospective teacher is often apprehensive about his knowledge of the subject to be taught. Fortunately, this problem is not only readily recognized but also lends itself to solution. It can be solved by the teacher candidate through self-study and by teacher preparation institutions through changing the amount, type, and quality of subject matter courses in the preservice program.

Throughout the last two decades, better subject matter preparation has been a major goal of the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), Commission on Science Education, the National Association of State Directors of Teacher Education and Certification (1, 2), the National Science Foundation, and most institutions preparing science teachers. Yet, the problem persists!

A common criticism is that the programs have not provided adequate models whereby teachers in training learn science via inquiry strategies similar to those that they are expected to employ in their own teaching. Nor do the programs provide adequate models of integration of several science disciplines or of science with other disciplines to adequately prepare the prospective science teacher to teach the integrated courses that are being advocated. A desirable strategy would be to provide model interdisciplinary courses as part of the teacher education program, if, as is widely assumed, teachers tend to teach as they have been taught.

Education Courses are Irrelevant; the Gap Between Theory and Practice.

The Research on Science Education Survey (ROSES) revealed that prospective science teachers felt that education courses are irrelevant to their future career. These researchers reported a high frequency with which the courses are denigrated as being useless or a waste of time (30). This negative attitude is surely reinforced by the many instances that Barnard

> . . . and others can cite in which student teachers have been told by the science teacher in whom they have been assigned to forget all that 'idealistic stuff' they were taught in their methods courses at the college because it just doesn't work. And you know, a lot of it doesn't (5:42).

Bridgham seems to concur in writing that

> . . . schools and colleges of education. . . . are often accused . . . of describing an ideal set of affairs, what ought to be done, without much consideration of the practical constraints of the classroom. Teachers, on the other hand, often seem to equate what can be done in a situation with what has been done (8:236).

Fuller and Bown substantiate the charge of irrelevancy in that the empirical literature yields the disturbing conclusion that teachers do not feel helped by college-based teacher education (16). If so, it is essential that the professional component of programs for both preservice and inservice science teachers be modified so that they will be viewed positively by teachers for whom the programs have been designed. As Bridgham concludes, "It is only as these courses can reasonably claim to make the beginner's apprenticeship a more adequate preparation for teaching that they deserve a place in the program of teacher training" (8:236).

Recent Graduates of Science Teacher Training Programs do not Know How to Teach in the Real World of the School.

Rutherford and others charge that serious deficiencies in the original training of teachers include the lack of a coherent philosophy of teaching and learning, a severely lacking repertoire of teaching skills and strategies, and attitudes that mitigate against the acceptance of change (36). Rutherford and Hurd (22) concur that although new content and new materials have been developed for science teaching using an inquiry teaching-learning strategy, most high school science courses are being taught pretty much the same old way. If, as the ROSES study revealed, science educators are placing considerable emphasis on the "new" courses and inquiry teaching in their programs and feel that inquiry teaching would become more widely practiced by the 1980's (30) one must question the impact that these programs have on the teachers in training. Sharp says that "Virtually nothing in his 'professional' training prepares the teacher with basic skills of inquiry" (39:18). Although inquiry as the prime goal of science education is being challenged by requests for science instruction that is somewhat more humanistic and with a greater emphasis on social aspects of science (15, 35), the problem of preparing teachers to teach for either the inquiry or more humanistic outcomes, or both, is likely to persist.

Fuller and Bown have identified several concerns of individuals in the process of becoming teachers as being about pupils, the teaching situation, and survival in the classroom.

> Most intense are concerns about class control. These may originate in the teacher--in feelings of inadequacy, in dependency, or in plain lack of skill. But the situation, including attitudes of others, is often the culprit, at least in the eyes of the teachers themselves. In fact all of the logistics of the class--its size, the involuntary status of students, and variable parental and community standards--make teaching difficult, particularly for the beginner. . . (16:39).

Thus, it seems pretty safe to conclude that most teacher education programs meet the needs of teachers in a sequence different from the sequence in which teachers feel the needs. If preservice programs do not better meet the needs of teachers, school administrators will continue to be dissatisfied by the prospects of having to train recent graduates of science teacher preparation programs to teach science in the real world of the public school.

Preservice Science Teachers are Often Provided with Poor Models of Science Teaching.

Schools located near teacher training institutions are often asked to provide field experiences, including student teaching, for large numbers of prospective teachers. Requests for such assignments in these schools often exceed the capacity of the schools to provide exemplary experiences with highly competent master teachers. Thus, the cooperating teacher is rarely trained to train teachers, may not be a good teacher himself, and is often given little support by his school. Rowe reports that prospective elementary teachers "rarely observe science taught in elementary classrooms . . . because there is little science instruction going on in the schools and what there is usually occurs late in the day" (35:372).

Guesses by classroom observers, after a decade of efforts to develop new science programs, train teachers in their use, and support of schools in the implementation of these programs, were that perhaps no more than fifty percent of secondary science teachers were teaching the new programs in a manner consistent with the specified goals (22). While many cooperating teachers provide good models of effective science teaching, it is clear that the number is inadequate.

Empirical studies by Horowitz (18) and others show that the cooperating teacher and the school have a profound impact in that they have been found to change student teacher attitudes in as little as two weeks. Fuller and Bown (16) cite research which shows that student teachers often change from a humanistic to a custodial approach stressing bureaucratic order and control. Bush and Enemark (11) report that "a comparison of empirical studies of student teachers and first-year teachers shows that both groups are susceptible to the school's hidden 'teacher education program'." Thus, it is evident that cooperating teachers should be models of effective science teaching and that the schools should be supportive of student teachers as they try new things, some of which are likely to fail.

Prospective Science Teachers are Often Provided Inadequate Supervision by the College or University During Their Field Experiences, Student Teaching, or Internship.

Teacher training institutions are often criticized by the schools for failing to provide adequate supervision for prospective teachers in the field. A majority of the students interviewed in the ROSES study reported having been visited by the college supervisor no more than three or four times during their practice teaching. They reported having had approximately the same number of conferences with the college supervisor about their teaching. We are reminded by Rutherford that the university supervisor is often a graduate student who, being overloaded, visits the teacher-in-training all too infrequently (36). Often he is not trained as a supervisor and has not been a cooperating teacher.

Criticisms of inadequate models of effective science teaching in the schools and inadequate supervision on the part of the college supervisors appear to be valid. Empirical studies demonstrate that the cooperating teacher and the school have a definite impact on the attitudes and teaching behaviors of student teachers. They show that immediate feedback to beginning teachers concerning their teaching is most effective in changing teaching behavior (17). This is especially true when lessons have been designed to develop predetermined teacher behaviors that have been accepted by the teacher in training. Frequent feedback from both the cooperating teacher and supervisor tends to relieve the frustrating uncertainty in the mind of the teacher in training as to "how he is doing." It is apparent that the problem of providing good models of effective science teaching and support for the beginning science teacher by the cooperating teacher, the school, and the college supervisor must be solved.

Science Educators Do Not Know What It Takes To Prepare An Effective Science Teacher.

"Eighty percent of the four-year institutions of higher education in the United States operate teacher education programs and there are thus nearly fourteen hundred sites for teacher education in this country" (14:55). Most of these institutions prepare elementary teachers to teach science and many have special programs to train secondary science teachers. Newton and Watson concluded from the ROSES study that

> . . . the diversity of programs in science education is very great. There are examples of almost every conceivable pattern to be found somewhere in the nation.

They state that

> . . . the lack of basic objective evidence on the effectiveness of teacher education programs is striking.

and speculate that

> . . . chaos in the profession . . . is probably one consequence of the inability of science educators to confer about and agree upon the goals and the structure of the teacher preparation program in the sciences (30:120).

This problem is compounded by the fact that once the goals have been agreed upon, there is little, if any, definitive research on the optimal way to attain the goals. Also, there is a lack of empirical data that reveal a clear cause and effect relationship between specific teacher behaviors and student attainment of specific desired competencies or behaviors (17).

COMPETENCE OF SCIENCE TEACHERS

The concept of competence of science teachers is not new. Throughout this century, programs for the preparation of science teachers have stressed, to varying degrees, competence through college or university preparation in each of three areas: general or liberal education, breadth and depth of preparation in science, and professional or pedagogical training. Two, of many possible examples, are considered as evidence of constancy of the general concept of competence of science teachers.

In 1932, Powers wrote

> A program for the education of teachers must be so planned as to meet the needs of teachers preparing for service in the schools. Education should liberate from ignorance. The liberally educated person should be able to make intelligent adjustments to stimuli which are associated with rich living (34:325).

With respect to science, he stated

> It is impossible to teach any subject matter without an adequate background of subject matter training . . . and qualifications for success are greatly strengthened by training in related sciences (34:333, 335).

In 1974, one of the competency based Standards for the Approval of College and University Teacher Education Programs (40) includes similar components; one-third of the coursework in general education, one-fifth professional education, one-third teaching specialty, and the remainder being elective. Justification for the general education component is

> . . . to prepare broadly-educated teachers who view education as a life-long pursuit and who serve as models of educated persons for their students. It enables the prospective teacher to relate academic concerns to contemporary national and world events (40:6).

With respect to the professional preparation and the subject matter specialty,

> The professional education component prepares the prospective teacher to perform effectively in the classroom environment. The teaching specialty component provides the content to be taught . . . plus advanced and supplementary knowledge necessary for perspective and flexibility in teaching (40:6).

Competency-Based Teacher Education

A decade ago the language of Competency-Based Teacher Education (CBTE) did not exist (37). Currently CBTE is being proposed as a possible solution to many of the shortcomings of teacher education. Schalock, in a recent position paper of The Consortium of CBE Centers (37), writes,

> . . . approximately half of the teacher education institutions in the nation have begun either to operate, develop, or plan CBTE-type programs. Even more remarkable is the fact that within this same period (1969-1975), approximately half of the states within the nation have adopted or are moving to adopt certification and accreditation standards that call for such programs (37:1).

Gage and Winne (17) identify PBTE (synonymous with CBTE) as "unquestionably the dominant new movement in teacher education during the last decade." Yet, it is interesting to note that Texas, "the first state to mandate competency/performance based teacher education in every teacher preparation institution back in 1972 . . . apparently became the first state in the Union to abandon its mandatory scheme" (29) two years prior to the 1977 deadline for compliance.

For working purposes, Gage and Winne define PBTE as

> . . . teacher training in which the prospective or inservice teacher acquires, to a prespecified degree, performance tendencies and capabilities that promote student achievement of educational objectives. 'Teacher performance' refers to observable behaviors, both verbal and nonverbal. 'Tendencies' refers to what the teacher typically does in the average or normal teaching situation. 'Capabilities' refers to what the teacher is able to do when trying his best. Both tendencies and capabilities are assessed in terms of an explicitly stated level of mastery so that if the teacher does not perform at or above this level, he is considered to be inadequately trained. Finally, the performance tendencies and capabilities are selected and defined with reference to their effects on student achievement (17:146-147).

The Gage and Winne definition is in good agreement with that of Stanley Elam's early and, what Schalock identifies as, widely accepted definition of CBTE

> . . . in performance-based programs, performance goals are specified, and agreed to, in rigorous detail in advance of instruction. The student must be able to either demonstrate his ability to promote desirable learning or exhibit behaviors known to promote it. He is held accountable, not for passing grades, but for obtaining a given level of competency in performing the essential tasks of teaching; the training institution is itself held accountable for producing able teachers. Emphasis is on demonstrated product or output (37:2).

A CBTE status report (24) prepared for the Association for the Education of Teachers in Science (AETS) concludes that there is a "strong trend toward the CBTE approach at this time" (1973-1974) in teacher education programs for secondary school science teachers. The study committee preparing the report wrote that CBTE "seems to be firmly established in the special teaching methods and psychology area, and much less visible in the subject-matter and history and philosophy programs" (24:36). Elsewhere in the report, the committee states

> Many problems were encountered in our survey of the competency-based teacher education programs submitted by preservice institutions. An attempt was made to classify competencies according to a standard system, but the competency statements submitted were so different in quality, form, nomenclature, and criteria for mastery as to make this very difficult. For the most part, the responding institutions supplied either collections of statements from which no program could be deduced or descriptions of programs from which no competencies could be deduced. Hence, it was rather difficult to conclude who is involved in a CBTE program, and to what extent, on the basis of these data.

> . . . Few of the 'competency' statements submitted specified goals in (the) rigorous detail (required by Stanley Elam's definition of CBTE) (24:26).

A review of the literature on programs for the preservice preparation of science teachers for the purpose of writing this chapter suggests very limited progress toward CBTE. While Morris (27) describes a "Minimal Competency Program for the Preparation of . . . Innovative Secondary School Science Teachers," few programs are apparently well enough developed to be reported in the professional journals.

In making a case for the need for research-based data relative to CBTE, Schalock states

> Whatever the factors that have attracted the educational community to the concepts of CBTE, the nature of the educational returns that can be expected from the movement remains at the level of projection.
>
> . . . there is as yet little evidence that the educational returns from such programs are greater than those from traditionally designed programs.
>
> . . . it can be argued that because of assumed better preparation, or assumed better selection due to more stringent exit requirements, prospective teachers going through CBTE programs will have greater success as they enter the profession than will teachers from non-CBTE programs. As yet, no one knows this, in fact, to be the case.
>
> . . . we have no firm evidence that one set of teaching competencies is more productive of learning in children than another set; that one level of competency definition is better than another level; that one approach to program organization is better than another in bringing about desired competencies (37:3).

He is concerned that ". . . persons who control the funds in support of teacher education programs, and persons who have been led to expect significant changes in the educational system as a function of CBTE programs (will be) demanding to see data in this regard" (37:3) and that satisfactory data will not be available.

Shalock and others have concluded that to date ". . . there is simply no sign of an emerging technology of assessment that meets the demands of competency-based teacher education movement" (17:165).

Gage and Winne (17) report that the rapid growth of CBTE has been accompanied by internal dissention and external criticism on basic issues. A strong protest against CBTE has been made by Combs (13) and others who emphasize the importance of "humanistic" education that is defined by Blume as education that

> . . . helps our young to develop compassion, concern for others, faith in themselves, the ability to think critically, the ability to love, the ability to cooperate with others, the ability to remain in good health, and, above all, the ability to remain open to other people and new experiences (7:411).

A humanistic teacher education program, as outlined by Combs (13) is highly personal and dependent on (a) the prospective teacher's development of a belief system, (b) is a process of "becoming" a teacher, (c) emphasizes meanings rather than behaviors, and (d) should focus more on the teacher's subjective impressions and less on objectively gathered information on the process of teaching and learning. Although Combs and other humanistic educators hold that CBTE is the anthesis of humanistic teacher education, Gage and Winne take the position that it is not. They argue that

> To the extent that humanistic teacher education defines goals for its trainees, and determines the achievement of these goals with measures of teacher performance and student achievement, it is itself performance based. Thus, the humanistic and CBTE orientations are not necessarily antagonistic, and in our judgments, benefits can be derived from their concurrent use (17:151).

As defined in this chapter, CBTE depends on the ability to specify teacher performances that promote specific student achievement. Yet Gage and Winne, like Schalock and his study committee, could find no truly experimental studies on the effects of teacher behaviors. They report that more than 100 non-experimental studies relating "naturally occuring teacher behaviors" to desired learning outcomes obtained relationships that are generally low. They do, however, identify a study by Wright and Nuthall (44) that found a multiple correlation of 0.89 between a combination of six teacher behavioral variables and student achievement which suggests that this relationship may be complex and that the problem of preparing and assessing the competence of effective beginning science teachers will not be easy to solve.

In support of CBTE, Gage and Winne find that the evidence for the effectiveness of clearly defined objectives and feedback about teaching performance is fairly constant. "When the information is explicit, clear, and keyed to specific aspects of teacher behavior, feedback results in improvement in the trainee's ability to perform according to a model" (17:152). They take what appears to be a reasonable position; that to go back to the state of teacher education before CBTE would be to throw away some improvements in practice that have already been attained. The fact that faculties of a large number of institutions preparing science teachers have been involved, one way or another, in the movement suggests that it is likely to have a lasting, although at this time undetermined, impact on the profession.

SOME CURRENT EFFORTS TO IMPROVE

The basic goals of programs for the preparation of science teachers have changed little in the early half-century since Powers wrote

> . . . it is assumed that the requisites for success in . . . teaching are: first, that the teacher shall be a liberally educated person; second, that he shall be a specialist in science; and third, that he shall be professionally educated in the sense that he will be familiar with the problems associated with teaching and in command of the techniques that are necessary for successful work in the classroom (34:xi).

Today, state guidelines for the development of teacher education programs and the resulting preservice programs designed by institutions preparing science teachers continue to identify and focus on liberal or general education, specialization in the subject taught, and professional preparation for effective performance in the classroom (40).

Yet, the general education of prospective teachers must change as society changes at an accelerating rate, thereby creating new problems and challenges including that of preparing students to live in a society that is certain to be different from that of the past or the present. With increasing population densities, redistribution of increasingly scarce resources, changes in our value system including the relative worth of work and leisure, and an accelerating knowledge explosion accompanied by rapid dissemination made possible by sophisticated electronic communication technology, the general education of the prospective teacher must continue to change.

Also, the nature of the science to be taught is changing as a result of research findings that fundamentally change man's concept of his natural world. Decisions must be made as to what science content is most worth learning and teaching. The debate continues on the relative importance of science content, the role of scientific inquiry and the so-called processes of science, integrated courses that deal with science-related social issues and problems, and the programs have been selected from those described in the recent professional literature including the nation-wide survey that resulted in the publication, In Search of Promising Practices in Science Teacher Education (3). The basic criterion for selection of these programs for presentation was that they appeared to be serious efforts to overcome the major criticisms of programs for the preservice preparation of science teachers discussed earlier in this chapter. It is recognized that the programs selected for presentation may not be unique and that other programs may be doing similar things and perhaps doing them better. If so, a major contribution would be made by sharing them via the professional journals.

Our concern here will be on "new" ideas for the preparation of effective science teachers, not on the numbers of teachers being prepared, how well the programs work, or whether they actually achieve the stated goals.

Science Preparation in an Elementary Teacher Education Program with a Humanistic Intent

The "New Education Program" started in 1969 and described in 1973 and 1974 at the University of Florida, Gainsville (32, 35), is based on the humanistic philosophy of Combs (13). There are no classes; beginning in the junior year, students are continuously involved in field experiences in the public schools to provoke a need to know and to help the student joint theory and practice. The program is individualized so that different students complete their work and graduate in different amounts of time, with each student assuming responsibility for his own education.

When he enters the program the student is assigned to a seminar consisting of 30 (beginning and experienced) students and a seminar leader. A student remains in the same seminar section, guided by the same professor, until he completes the program. The seminar leader serves as a program counselor and conducts sessions designed to help students integrate their experiences. In addition to the seminar leader, there are faculty members who constitute what is called a substantive panel for the team. This panel includes a person who is responsible for the instruction in science.

Each academic area has a set of learning activities that are classified into two groups: those that are required and those from which choices can be made as part of the process of acquiring competency. There is also an arrangement for negotiation whereby a student may produce a plan of his own which, upon approval by the appropriate faculty, may be pursued in lieu of the elective activities.

The science program (as of August, 1972) lists eleven learning activities in science with four to be completed by each student and includes those that pertain most directly to science content and processes. Also, these activities suggest strategies used to individualize the science requirement, require the student to assume responsibility for his learning, and relate the study of science to elementary teaching. The four required activities are:

a) Examine and perform the activities for six units from at least two of the new programs (AAAS, ESS, SCIS).

b) Select and carry out two laboratory investigations in each of the following areas: Physical Science, Life Science, and Earth Science. The activities must be selected from at least three different sources.

c) Present evidence that basic information has been learned in a minimum of two areas of physical science and of two areas of biological science. At least two sources of adult material must be used for each area.

d) Demonstrate an understanding of the "Process of Science" and give concrete examples of how they can be developed with elementary school children.

A study revealed that graduates of this program scored as well on a general science content knowledge test as did students completing 15 term hours of science credit with strong content emphasis. However, one third of both groups scored lower than the top 10 percent of sixth graders. This finding resulted in the requirement that each prospective elementary teacher continue his study of science until he could score at or above the 75th percentile for end-of-the-year 9th graders on a general science content test, different forms of which could be taken several times if need be. A science content module was designed to help students who need to improve.

Rowe reported that under the field-based, seminar-centered program described, science as a subject of central interest suffers because students rarely observe it taught in the classroom and only occasionally are they called upon by the classroom teacher to plan any science lessons as part of the on-going program. This situation could be changed through careful three-way cooperative planning involving the classroom teacher, the teacher in training, and the college or university supervisor.

An Integrated Science Program for Preservice Elementary Teachers

The ultimate goal of this program, initiated in 1972 at Purdue University, is the development of teachers who are capable of teaching science to children through inquiry (31). Assuming that teachers will teach as they have been taught, the program is designed to provide experiences for prospective elementary teachers in which scientific knowledge is presented in an inquiry manner. Another important goal is to effect a more positive attitude toward science and the teaching of science.

Prospective elementary teachers begin the program the first semester of their freshman year with a science methods course and continue with the same team of instructors for six semesters, for three semester hours of science each semester. Integrating science content with methods of instruction with experiences with children, the program is designed to "escalate" over the three-year period.

Following the science methods course are two semesters of biology and two semesters of a combined physics/chemistry course, all terminating in a capstone applied outdoor environmental studies course planned to include sex education and drug education. Each of the instructors on the team is either a biologist (and an educator), elementary science educator (and a geologist) or an instructor holding a joint appointment in chemistry and education or in physics and education. The two instructors who are co-directors of the project progress with the prospective teachers throughout the six semesters, thereby allowing time for extended observation which makes remediation, rather than mere identification of individual weaknesses, a reality.

Scientific knowledge is structured around a major conceptual framework which has as its theme "Man and His Environment" as related to "Survival in the Face of Change." "How do I know . . .?", "Why do I believe . . .?" and "What is the evidence that . . .?" are typical searching questions used to develop understanding of science concepts as opposed to rote memorization that is often facilitated by the lecture-demonstration type of science course. To assess understanding, teachers interact with students on a one-to-one or small group basis. Students' responses to probing questions provide deep insights into how they perceive a particular concept or idea. The goal of the probing questions is not simply to determine the correctness of a response but to lead to a self-correction of faulty thinking through discussion and questioning.

In the science methods course, major national curriculum projects such as SAPA, SCIS, and ESS are used in the presentation of model lessons. Concurrent with classroom instruction, the prospective elementary teachers are introduced to a series of process modules through which they move independently. In conjunction with this, they are introduced to performance objectives, sequencing, and microteaching. Each student plans and executes two lessons which are taped, evaluated by students using an interaction analysis technique, and then evaluated with an instructor.

It is estimated that the amount of subject matter to be studied may be reduced as much as 90 percent over that studied in a traditional 18 semester hour sequence. This results from the fact that most of the students will be experiencing for the first time the necessity of generating original ideas, models, and generalizations based on their own observations. They must be given adequate time to engage in problem-solving activities that are consistent with the nature of science. As they collect data and arrive at tentative explanations, they must be allowed to test their ideas with their peers and to articulate the ideas to their instructors. It is assumed that only by allowing students to make mistakes and to sharpen their ideas through peer interaction and class discussion can they experience the personal satisfaction that arises from achieving personal understanding through their own intellectual efforts.

An Introductory Course in Physical Science for Prospective Elementary Teachers

Arons (4) describes a course in physical science developed by the physics department at the University of Washington to prepare prospective elementary teachers to handle the new elementary science curricula. The program is based on existing materials: College Introductory Physical Science, with selected materials from Project Physics. It is designed to meet the student at his level of intellectual development which McKinnon and Renner (26) have documented, in the case of a majority of the students served by introductory science courses, as being concrete operational or below on the Piagetian hierarchy. Arons and his cohorts have found that a "still larger segment of the students have no practice in the most basic arithmetic reasoning" (4:31). A major effort and substantial amounts of time are devoted to an attack on these problems of intellectual development.

Pairs of students are provided unit outlines, each of which guides their work for a period of one or two weeks at their own pace. The unit outline indicates a body of experimental investigations and text material, problems to be solved, questions to be answered, and a specific description of what the student should be able to do when he has completed the units.

The course content deals with big ideas such as the description of motion, the model of the solar universe, the atomic-molecular model, and the unification of terrestrial and celestial phenomena in the Newtonian Synthesis. As the course progresses, efforts are made to "spiral back" and more fully develop basic concepts studied earlier, many of which are common to the elementary science curricula. Laboratory investigations often digress into investigations along the lines of the elementary science curricula.

When the students feel that they have completed a unit to their satisfaction, they answer a few written questions or have an oral interview with a staff member to check their grasp of the material before going on. While the initial level of understanding of the ideas and lines of reasoning may not be high, the students are seldom sent back for additional work in the same unit. Deeper understanding is cultivated by continually spiraling back to earlier ideas, invoking these ideas repeatedly, and using them in new juxtapositions.

Laboratory work, problem solving, and informal conversations among students and faculty go on in every class session which is held in a laboratory. When a group of students is ready, they are drawn together for a discussion which strives to organize ideas and to open perspectives that students are not likely to see without guidance from a teacher.

The questioning is Socratic; the students are led to answers, not told. Cutting across subject matter content in the new science materials, questions are continually raised as to "Why we believe . . .?", "How do we know that . . .?", and "What is the justification for . . .?" Because of the discovery that much of what students have been "taught" previously has left them with the notion that knowledge resides in names which they can use with "great abandon but without any idea of what the words mean or what experiences give them sanction . . . a slogan of this course has become 'the idea first and the name afterward'" (4:31). On checkouts and at the ends of units and on tests and quizzes, the instructor insists that the student be able to describe an idea in simple words before he acknowledges that he understands the meaning of the technical term.

In addition to cultivating aspects of logical thought and conceptual understanding, the faculty seeks to have students see science as a product of human imagination--an enterprise of enormous power and profound limitations. Toward the end of the course each student is given a movie camera for a day or two. They are to come back with 30 seconds of film which they believe to be connected with the ideas and concepts that they have studied. When the roll is full, the film is processed and shown in class. Each student presents his own film and explains the physics that he saw. The richness of many of the films is surprising and rewarding, and everyone has a good time.

A Cooperative Program to Prepare Undergraduates to Teach Science in Inner-City High Schools

A group of science and education faculty members at Brown University, in cooperation with members of the Providence (R.I.) School System developed an Inner-City Teachers of Science (ICTOS) program (25, 42). The program was designed to select and prepare undergraduates having a commitment to teach science in inner-city high schools characterized by having a large proportion of minority group students, a small number of students enrolled in science, and lack of adequately prepared science teachers.

Beginning as freshmen, the Brown model has students studying science in courses specifically designed to stress the unity of the physical and biological sciences and to provide in-school science experiences and activities, particularly in the laboratory. The introductory college science courses, conducted in a discussion-demonstration format, demand in-school experiences in which college students interact directly with high school science students and teachers. The prospective science teacher serves as an aide to high school teachers, performing duties such as tutoring, assisting small groups of students, helping students in the laboratory, preparing demonstrations, arranging field trips to the university, assisting with curriculum development, offering "guest" lectures on selected topics in which he/she is especially competent, and other similar activities.

An interdisciplinary Advanced General Science course is taken in the junior or senior year, after the student has completed the specially-designed basic science courses in physics, chemistry, and biology. The advanced course is designed to illustrate the interrelation and overlap of the various scientific disciplines. The science courses are designed for prospective teachers, not for inner-city high school students. It was the intent of the team that developed the program to impart an attitude and a general approach to the teaching of science rather than to instill specific procedures and facts that the teacher-candidate is expected to carry over into his own teaching. One important attitude is that the science taught should be made relevant to the world of the student. It is assumed that if science can be taught in such a way that it is interesting and relevant to the teacher-candidate, this should affect how they, in turn, will teach science to their students.

An interdisciplinary education course, Inner-City Education, utilizing the expertise of members of the Anthropology, Economics, Education, Political Science, and Sociology departments whose interests are related to the inner city is taken throughout the sophomore year. The spring semester consists primarily of field work that provides the student an opportunity to test and refine the theoretical constructs formulated in the first semester in inner-city reality, thereby introducing the student to the environment in which he expects to teach in more depth than required in the basic science courses.

Methods and Materials of Teaching Science in the Inner-City Secondary School is jointly planned and taught by high school and university personnel. The course consists of two components: lectures and discussions conducted by a member of the university staff whose specialty is science education, and a practicum, conducted by a master teacher in a cooperating school, which is concerned with classroom applications and adaptations of the theory developed in the first component. Practice teaching, two periods per day for a semester, and a course on the design and construction of inexpensive experimental and demonstration apparatus to illustrate some basic science principles constitute a year-long course the senior year.

A Program to Change the Outlook and Teaching Practices of Cooperating Teachers in Order to Provide "Better" Models of Effective Science Teaching

Berger and Goldberg describe an attempt by the science education faculty of Richmond City College of the City University of New York to change the outlook and teaching practices of cooperating teachers so that they, in turn, could shape the attitudes of their student teachers in a direction consistent with the goals of the college program. It was assumed that through a jointly planned cooperative program, the classroom science teachers would be more receptive to the new ideas and methods of their student teachers and would be able to provide positive reinforcement for less traditional approaches. It was further assumed that increasing the classroom teacher's responsibility for supervision of student teachers would cause him to become more introspective and self analytical of his own teaching style. To reinforce this role, the classroom teachers were recognized as college faculty and given the title of adjunct lecturer. Major responsibility for the evaluation of the student teachers was placed in the hands of the cooperating teachers. The college supervisors were then free to act as consultants in classroom situations and in curriculum development.

Each student teacher was given full responsibility for at least one class throughout the semester of student teaching, a pattern that differed sharply from the prevailing situation which gave them little opportunity to teach and almost no responsibility. Each cooperating teacher became responsible for guiding the growth and development of his student teacher, kept extensive anecdotal records, wrote observation reports, and evaluated specific components of the teaching styles and approaches used by his student teacher.

An important feature of this cooperative program was the weekly after-school seminar at which the cooperating teachers, student teachers, and college faculty discussed issues and ideas involving the teaching-learning process. Inquiry lessons, kinds of questioning, open-ended laboratory exercises, motivations, and pupil evaluation were among the topics explored. Extensive use of video tapes in evaluating teacher and class performance were utilized to develop further insights into the areas mentioned.

A significant aspect of the seminars was that the college personnel were able to appreciate better the daily teaching routines and pressures faced by the cooperating teachers and were able to understand how these conditions contributed to some of the attitudes and opinions initially expressed by the teachers.

Data obtained anonymously on an open-ended, free response type of questionnaire revealed that the student teachers' professional development as a teacher was "greatly influenced" by both their cooperative teacher and college professors whereas those in the traditional program replied that the college professor had "very little" influence or were "moderately influential." The student teachers were favorably impressed with the cooperative nature of their supervising teachers and an atmosphere in which they could attempt new approaches in science teaching. They responded positively to the opportunity to have an interchange of ideas and to learn the views of the cooperating teachers and professors through the seminars. An examination of responses by the cooperating teachers to an open-ended questionnaire revealed that they were enthusiastic about the program and were open to different approaches to science teaching.

A Program Designed to Provide Science Teachers with Experiences of Escalating Sophistication at Several Levels in Both Inner- and Outer-City Schools

The preservice program in science education at The Ohio State University is a five quarter sequence beginning in the junior year that combines educational theory with classroom practice (19, 20). Prospective science teachers work with pupils in instructional and community settings at the elementary, junior high, and senior high school levels. An optional sixth quarter internship in alternative (non-school) educational programs is being reviewed for possible inclusion as part of the core of the senior program. Focus is on the individual junior high school student, the individual elementary school pupil in small groups, high school students in laboratory and classroom settings, a problem-solving attitude toward pedagogical problems in science education, and synthesizing the experiences and skills gained in previous quarters through full-time student teaching. Objectives of each of the quarters are stated in behavioral terms.

Each college junior works as a tutor for one period twice a week in a junior high school with a pupil who has been identified by a classroom teacher as one who needs help in science or who could benefit from more individual attention. Audiotapes are made of some tutoring sessions for analysis by the tutor and discussion in conference with the university supervisor who ordinarily continues with the teacher-candidate through at least two quarters of the junior year. A university instructor is present as a resource person to work with the cooperating teachers, the teacher-candidate, and the school staff in general. Two seminars are held each week. One is held in the school to enable the cooperating teachers to participate in discussions centering on problems encountered in tutoring situations and other experiences in the school. A formal meeting is held each week on campus during which the teacher-candidates are presented with information concerning concept formation, processes of science teaching, analysis of cognitive development, lesson planning, and teaching techniques presented by the university instructor working with the program and other faculty members. The student also participates in a series of microteaching sessions designed to focus on teaching skills such as questioning, introducing a topic, and presenting an inquiry lesson.

During the second quarter each student is primarily responsible for working with small groups of elementary school pupils in science lessons and in assisting the cooperating teacher in other activities, observing at other grade levels, and becoming acquainted with the school and its staff. One seminar each week is devoted to discussion of problems or situations encountered in the elementary school and aspects of effective teaching such as establishing favorable learning climates, teaching techniques useful for small groups, methods of analyzing student interactions, and ways of utilizing individual differences in science teaching. Additional formal on-campus sessions utilizing the expertise of members from other faculties are concerned with topics such as behavioral modification, classroom management via positive reinforcement, cognitive development, concept formation, and interpersonal relations. Each student completes a case study of one pupil in his small group and conducts a Piagetian interview with the child who is the object of the case study.

The focus of the third quarter is on methods of teaching and learning secondary school science. Students are assigned in pairs to a secondary school science class in their major science content area. It is expected that these students will have regular opportunities to conduct laboratory activities and to assist the teacher in other classroom duties. Seminar topics and activities focus on special methods for teaching science in the major content area, under the guidance of the student's major advisor.

During the fourth term, students are assigned to work with cooperating teachers as teaching assistants for five weeks in an inner-city school and five weeks in an outer-city school four periods a day, five days per week. It is anticipated that these college seniors will provide much help as junior members of "instructional teams" by preparing and conducting demonstrations, assisting in the laboratory, preparing instructional materials, assisting in evaluating student progress, and work with students in need of special help. In addition, the student has an opportunity to teach an entire class for three to four weeks during the five weeks of involvement in each school. Seminars focus on understanding school-based experiences in a framework of principles, practices, and philosophies of secondary education. There is additional work in general methods of teaching science and in developing instructional materials to be used in the schools and in future teaching. The students are expected to become aware of many of the "realities of the schools" by observing widely throughout each school, talking with many school personnel, by informal discussions with pupils, by attending faculty meetings and after school functions, and by studying the socio-economic factors in operation in the school's attendance area.

Full-time student teaching with a cooperating teacher with whom he has worked a previous quarter is designed to permit the student to take immediate responsibility for two classes and very quickly assume total responsibility for three classes, doing almost everything that is expected of a regular teacher. It is anticipated that the cooperating teacher and student teacher will plan teaching situations in which they work together as an instructional team, thereby enriching instruction and learning from each other. Near the end of the quarter it is anticipated that the student teacher will assume the full teaching and supervisory load carried by a regular teacher.

A Minimum Competency Program for the Preparation of Innovative Secondary School Science Teachers

A minimal competency program for the preparation and support of innovative preservice science teachers is described by Morris (27), Indiana University Northwest at Gary. The introductory phase of the program is described as a transition from a traditional teaching methods experience at the university followed by student teaching to the goal of a cooperative competency-based program that provides in-school experiences with model teachers beginning as early as the sophomore year.

The program extends over a one-semester methods course plus eight weeks of student teaching. Teachers and administrators of the participating schools have committed themselves to the design and implementation of individualized study courses, integrated science courses, independent study courses, or combinations thereof. The classroom teachers are provided with lists of the competencies and copies of the instructioual materials used by the preservice teachers in the campus phase of the program.

The minimal competency model, consisting of instructional objectives, instructional strategies, and evaluation and feedback operates at two levels. The preservice course itself was developed according to the model, with university instructors exhibiting appropriate teacher behaviors. The same model was then utilized by the preservice and inservice teachers in developing programs for secondary school science students. Thus, the prospective teachers were taught in the manner that they were expected to teach.

Small university-based seminars during the first few weeks set the tone for the program. Value-laden questions concerning science education and science teaching were utilized to identify topics for subsequent seminars which were held in the schools after the first four weeks. During the first few weeks in the schools, emphasis was on building interpersonal relationships with students through informal discussions with students on a wide variety of topics, and tutoring of individuals and small groups of students. Emphasis was on teacher behaviors which have a positive effect on the learning environment. Information gained in this way was used by the preservice teacher in the design of an instructional learning package. Most of the university-based learning activities consisted of individualized instruction modules following the model described earlier.

Based on the belief that many of the teaching competencies would be acquired best through continuous interaction with school children, the program was designed for the preservice teacher to meet regularly with classes of experienced teachers throughout the program. As competencies were acquired in the areas of instructional objectives, instructional strategies, and evaluation and feedback, each preservice teacher consulted with an experienced teacher and they cooperatively identified a needed learning module for use by the secondary school students.

Morris lists a rather extensive set of major behaviorally stated objectives in the areas listed earlier. Competency assessment instruments, techniques, or strategies are not described in similar detail. Competencies must be demonstrated in the classroom before the preservice teacher will be recommended for certification.

By the end of the methods phase of the program the preservice teacher had participated successfully in every aspect of teacher behavior in the classroom and was ready for student teaching. Every attempt was made to place the student teachers in classrooms which were already innovative or were developing such a program.

Some advantages of the program were described as interaction with secondary school students in the science classroom, cooperative school-university development of a preservice teacher education program, innovation through curriculum development by both the preservice and classroom teacher, and modeling of effective instruction throughout the program.

A LOOK TO THE FUTURE

> However viewed, the real world is one of change, complexity, and uncertainty. The probable world over the horizon is even more so (9:295).

Education, like science, may be viewed both as product and process. Science, as process, is a dynamic, creative human endeavor to comprehend the "real world" of nature. It has resulted in unexpected rapid changes in mankind's concept of that world. A relatively small number of relationships (laws) and conceptual schemes (theories) have been invented by scientists to make the complex "real world" of nature more comprehendable. Perhaps the greatest certainty in science is the uncertainty of scientific knowledge; it is certain to change as a result of continuing inquiry into nature.

Education, viewed as a dynamic, creative human endeavor, is the process of enabling one to cope with "the real world . . . of change, complexity, and uncertainty" (9:295). As in the case of science, the process of education requires first-hand experiences with the real world, knowledge of how others view it, an understanding of the basis for our view of it, and skills and abilities requisite to solving a multitude of problems in a changing, complex, and uncertain real world for the benefit of mankind.

Effective science teachers must have a valid view of the real world of nature and understand how this changing view is a consequence of scientific inquiry. They must be competent in providing experiences that enable their students to a) attain a valid up-to-date understanding of the natural world, b) master some of the problem-solving skills of scientific inquiry, and c) cope successfully with the real world of change, complexity, and uncertainty as it pertains to them personally and to the larger society of which they are a part.

The "Perspective '76" theme of this yearbook requires that we look over the horizon to anticipate what may lie ahead for science education. Neither the successes of innovative teacher education programs such as those described earlier in this chapter nor the criticisms of conventional programs that we have presented should limit our imagination as to what might be. Rather, it is intended that they will provide direction and insight into the development of new programs to better prepare science teachers to meet the needs of their students for the last quarter of this century.

What are futurists (23, 41) predicting for the probable "world over the horizon"? It is certain to consist of a rapidly increasing population that will be more highly concentrated in urban areas. The global dominance of Caucasian populations is expected to decline. Social tensions related to ideological conflicts and the maldistribution of resources among the earth's inhabitants are likely to increase. Rich mineral deposits will continue to be depleted; energy sources will become less plentiful and more costly; starvation on an unprecedented scale could be a reality; pollution of the air, water, earth, and space will continue to plague mankind.

It is anticipated that the knowledge explosion will be accelerated due to ever expanding research and increasingly sophisticated electronic technologies that permit almost instantaneous global dissemination of information. Video and computer technologies will become increasingly essential to store, retrieve, analyze, and distribute vast amounts of information. We will live in an increasingly information-rich environment. Mankind has the technological capability of making the world a much better place to live or of destroying civilization as we know it.

There are certain to be surprises; unanticipated events t[illegible]ill result in a mismatch between predictions of the futurists and [illegible] world of the year 2000. It is inevitable that life styles will change. There is evidence of a new "quality of life" ethic by some populations in the industrialized nations. Difficult problems abound. Value systems are being challenged. Imaginative, creative, and skilled populations must be educated to solve satisfactorily a host of science-related problems, to enhance the quality of life, and plan acceptable alternate futures.

What sort of preservice education is needed to prepare science teachers who are likely to possess competencies and use instructional styles that will enable their students to contribute to the development of a better world over the horizon?

A basic assumption underlying the recommendations that follow is that, as is widely held, teachers teach (and students learn) as they have been taught. Therefore, teacher education programs should be models for the prospective teacher to emulate in teaching for the goals of science education. Programs for the preparation of effective science teachers should be characterized by:

Education for a Lifetime of Learning.

In a lifetime, one has a series of roles; childhood, student, family member, citizen, specialist for one or more economic careers, and user of leisure time. All of this in a changing world. We are uncertain as to what the world over the horizon will be like but we may be sure that it will be different in many ways from the world today. It is certain that in order to cope successfully in that world one must continue to learn.

Hurd suggests that "we should begin by rejecting as early as possible students who are . . . not really interested in a scholarly life . . . ." He continues, "A teaching candidate who . . . does not see the importance of spending at least three percent of his annual income on professional books, magazines, and activities throughout his entire career is not a person what we should encourage" (21:517-518).

Science educators and cooperating teachers with whom the teaching candidate prepares should themselves be adult models of lifelong learners. In-school and in-community experiences should be provided that exemplify "education as a seamless, open-access, learning continuum extending from early childhood through adulthood" (38:321). As a college or university student, the prospective science teacher should evidence self-learning attitudes and skills. He should take the initiative for his own learning and as many self-learning opportunities should be provided as he can use effectively. He should demonstrate academic competence through a high level of achievement in the learning activities that he undertakes. He should be resourceful in finding out through first hand observation, experimentation, consulting appropriate resource persons, and the study of authoritative literature. He should seek-out opportunities to gain a wide variety of experiences working with students and science teachers at several educational levels in both inner- and outer-city schools. He should develop confidence working with persons in the community who are able to assist him in providing stimulating learning experiences in science for his students.

Lifelong learning attributes of the prospective science teacher should include definite plans to continue his education, active membership in professional associations, and participation in professional meetings. Science educators and cooperating teachers should take the initiative in introducing prospective teachers to the profession through their own scholarly endeavors and by facilitating their students' participation in professional meetings, perhaps as guests.

Personalized Competency-based Programs

While the teacher competencies that are requisite for effective science teaching have not been established empirically or by consensus, no responsible person is making a case for incompetent science teachers. Yet, critics of existing programs, including teachers and the public that supports these programs, are questioning the competence of some of the teachers that we are preparing and certifying.

Previous experiences; existing knowledge, skills and abilities; attitudes and values; and goals of the prospective teacher will need to be taken into consideration in admitting candidates to a teacher education program, personalizing that program so that they are able to develop needed competencies, and recommending them for certification as beginning teachers. Personalized programs are, by necessity, competency-based if they are to build upon existing abilities and needs of the student in training and to result in an effective science teacher.

It is essential for the science educator, cooperating teacher, teaching candidate, and/or his students to be able to recognize effective science teaching in order to know when and if it occurs. For this to be possible, the learner, the teacher, or the observer must receive some clues that it is happening. It seems reasonable to assume that examples of clues that effective teaching is occuring can be articulated to serve as competency-based criteria for teacher education programs.

Criteria to be met by a given teacher candidate in order to demonstrate his competence for certification as a beginning science teacher could be agreed upon by an advisory committee consisting of perhaps an academician, a science educator, a science teacher, and the teacher in training. When demonstrated in an agreed upon manner at an agreed upon level, the teacher candidate would be certified as competent. A personalized, competency-based teacher education program should serve as a model for the prospective teacher to emulate in personalizing his own teaching and in assessing the competencies of his students.

The uncertain and changing nature of the real world suggests that teacher education programs should provide numerous opportunitiss for the teacher in training to identify and follow through in a scholarly manner areas of study that he has selected. While considerable guidance might be required for his initial personalized studies, the goal would be for the student to become proficient in learning on his own those things that he has identified as being important.

Competence in the Discipline to be Taught

Prospective science teachers will continue to need a strong preparation in science. Since the knowledge explosion is a phenomenon of science that has resulted in a decreasing doubling time that is roughly ten years at the present, an adequate preparation in science will require both breadth and depth of preparation in science and a predisposition by the prospective science teacher to keep up in science through self-study and continuing college or university study following certification.

College and university courses in the preservice programs for science teachers should be models of scientific inquiry as conceived by developers of curriculum materials such as Project Physics, BSCS, CHEM Study, and ESCP. These carefully conceived curricula present a valid up-to-date concept of science that accomodates change, uncertainty, and new ideas. They meet the needs of many of the science-prone students who currently study secondary school science. If modified properly they could meet the general education needs of students to cope successfully in the world over the horizon.

College or university level models of science courses that are consistent in emphasis with the elementary and secondary science curriculum projects of the 1960's are likely to be the most effective way of preparing prospective teachers to use these materials as intended by their developers, thereby overcoming a major criticism of existing teacher preparation programs. Also, it is conceivable that learning the structure of science disciplines through inquiry strategies would provide the necessary preparation and predisposition for the prospective teacher to design and teach science courses tailored to the needs of his students.

Interdisciplinary Studies

A strong general education in science will continue to be vital in order to make science relevant for the student who has no interest in a science-related career. A series of interdisciplinary studies drawing from several disciplines in the arts and sciences could constitute an important aspect of the general education of both the prospective science teacher and the students that he will teach. Science-related social problems would be studied in depth. An up-to-date knowledge base would be stressed; value systems challenged; alternative solutions proposed; probable consequences inferred; and acceptable trade-offs considered. Teams of faculty members representing several disciplines would help to assure an adequate knowledge base and a valid examination of the issues and problems from various points of view. Students would be lead to a scholarly, value-laden, interdisciplinary study of topics that they would help to select. Science educators would join with science teachers, academic professors, other educators, and science teacher candidates to study problems and issues related to science teaching that are suggested by in-school experiences of the prospective teachers. These interdisciplinary studies would exemplify education in which teachers and students are partners in a teaching-learning team.

Specialization in Teaching and Learning

Research-based theory should be applied to real situations in the school. Prospective teachers should be skillful in the employment of a variety of diagnostic techniques to assess accurately the educational needs of his students. He should be knowledgable of a variety of effective curriculum materials and capable of developing new materials when none exist or when the existing materials are inadequate. He should be effective in selecting, prescribing, and using modern educational technologies such as video-tapes, computer assisted instruction, audio-visual machines, and modern science equipment. He should be competent in assessing student attainment of the goals of science education and in prescribing both remedial and enrichment activities. He should be sufficiently competent as a science researcher to establish a teacher-student team to conduct some bona fide scientific research. He should be knowledgable of current literature in science, education, and science teaching. Most of all, he must be able to interact with students in such a way as to make science interesting and relevant to their present and future.

Cooperative Programs

The gap between theory and practice will be narrowed by rethinking the respective roles of the schools, science educators, academic professors, and the community in the education of the science teacher. A cooperative effort will be essential to prepare competent teachers for the world over the horizon.

The teaching profession is assuming an ever increasing role in defining certification requirements, approving teacher education programs, and monitoring the programs that have been approved (40). Relevant teacher training can take place only in the school where the prospective teacher can interact with real students and teachers in the real world of the school with its many problems. Academic professors will continue to be responsible for much of the college or university education of the prospective teacher by providing preparation in both general or liberal education and in specialization in the discipline to be taught. Science educators will need to more clearly establish relationships between teacher behaviors and resulting student learning and to provide guidance to prospective teachers as they work with students in a variety of capacities. The community, through the schools, must be supportive of science teacher education. Also, the science teachers that we prepare must be supportive of the needs and aspirations of their students and thus the community. In a changing, complex, and uncertain world, the preparation of effective science teachers must be a cooperative endeavor.

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CHAPTER 3

INSERVICE SCIENCE TEACHER EDUCATION

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Inservice education is the most important facet of science teacher education. What happens to a teacher from the beginning of the professional experience determines whether the thoughts and skills developed during preservice education result in quality science teaching. By its very nature, only parts of preservice education can be sufficiently relevant to the actual work experience to have major and continuing influences on science programs.

There are other limitations in science teacher education besides those inherent in preservice education. Many science teachers see the "packaged curriculum" as the way to improve teaching. Other teachers emphasize general teaching skills and deny any unique character to science education. Both emphases are valuable, but their singular pursuit has diverted us from adequately delineating the totality of inservice science teacher education. Science educators* may have forgotten the reasons for their activities and thus attack symptoms rather than causes. A conceptualization of the whole of inservice science teacher education, its form and its function, is drastically needed.

THE NEED FOR CONCEPTUALIZATION

Many approaches to inservice science teacher education are misdirected because they lack adequate conceptual frameworks for guidance. Definitions help, but most definitions are limiting because they merely summarize activities and thought to the present or are so general they mean something to everyone and nothing to anyone. We need identified goals and tasks to improve science teaching in specific contexts. These goals and tasks need to be derived from a comprehensive framework that inspires continuous improvement and steady evolution of inservice education.

The heart of a comprehensive framework for science teacher education is the concept of continuing education. Science teachers must understand what and why "they do." And this changes constantly. Without such understandings no amount of "how to" can help improve teaching. All providers and recipients of inservice education need to think and act in terms of available knowledge and sustaining productive inservice activity. Such an approach nurtures independence from external sources for improvement and increases the probability of improving learning.

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* Science educators are all persons whose professional activity is directed toward the improvement of science teaching; the largest group being elementary and secondary school science teachers.

Inservice education requires more advanced thinking than teacher-proof curricula, preschool institutes, minicourses, and training models. We must place ideas before things, evolution before revolution, continuous targeted efforts before shotgun therapy, and capitalize on our accomplishments.

The crux of the discussion is that a conceptual framework must be built on simple but fundamental questions; ever present in all inservice education.

What is needed?
When is it needed?
Where should it be done?
How might it be done?
How long should it last?
Who should do it?

One key to developing a comprehensive framework for inservice science teacher education is to constantly seek more in-depth answers to these questions, singly and combined. Another key is to pursue answers two ways: for generalization and for application to specific contexts. We should develop some general rules, but all students, teachers, communities, etc. are different. The framework must also be built on cumulative effects of the answers. To date, these things have not been done adequately. We need to seek a refined conceptual framework.

With the recognition that inservice science teacher education gets better as the framework gets better, past and present inservice efforts will be examined and followed with some thoughts on the future. Consideration will be given to functions and forms. Some practical ideas will be included but the underpinning thread is that the most dependable practical tool is good theory.

THE PAST (TO 1960)

The National Society for the Study of Education (NSSE) Yearbooks provide a useful set of benchmarks in documenting the evolution of inservice education. An early mention of inservice education was in "The Relation of Superintendents and Principals to the Training and Professional Improvement of Their Teachers" (9). It was assumed that the impetus for inservice activity comes from the administrator. Another point was that inservice education, not degree programs, was the major source of teachers' professional growth. It was also emphasized that schools must play a major role in planning and developing inservice programs because inservice impact is local.

1932

A Program for Teaching Science, the 1932 NSSE Yearbook (10), was a landmark document in science teaching. Chapters on subjects such as curriculum included teacher education by inference, but only one short chapter was expressly devoted to teacher education. However, some ideas will always be relevant to inservice education.

1. To contribute to the liberal education of students, a teacher should also be liberally educated (to perceive the concept and give it its proper due in the total). A liberally educated person has explored widely into fields of human thought and has a measure of command in some specialized field. Current practices are inadequate for prospective teachers to attain these standards for the education of teachers; they are not even approached (10:325).

2. There must be commitment to breadth and thoroughness of preparation. Sequence and the interrelatedness of the education are mandatory. The work should be considered as a whole (10:339-340).

1946

In Science Education in American Schools (11), inservice education was highlighted in two chapters on teacher education. In general, teachers were to be competent in both subject matter and methods. Science courses designed for science specialities, engineering, or liberal arts were not appropriate for the prospective elementary school science teacher, in part, because of the need to demonstrate the social function of science. There was a concern for the oneness of science and the role it canplay in solving problems. The intellectual significance of science was to be put in context, with an emphasis on the importance of field and laboratory activities, and breadth of content coverage.

Specific discussion on inservice stressed preparing for teaching throughout one's career. Preservice and inservice were not to be distinguished. Pertinent points about elementary school teachers included these:

1. Every school system should have a program of inservice education in operation. Concerns would include teamwork, regional problems and resources, new practices and innovations, and personal-social needs.

2. Planning should be democratic and cooperative.

3. Supervisory work should be part of the support system, not a mechanism for directed activity.

4. Provision must be made for individual professional involvement. Those who receive remuneration can be expected to assume larger leadership roles.

5. School committees should be established to facilitate the improvement of instruction. The committee develops policy and its members are volunteers. Teachers from all levels should be involved and involvement of various community personnel is highly desirable.

6. Outside consultants should be used to perform specific tasks. Long term planning is a must and one outcome of activity should be the development of internal leadership personnel.

7. There should be available professional courses in elementary science.

8. Observation of teachers at work is very important.

9. Clinics could be organized at the building level which involve teachers and consultants in the analysis of instruction.

10. Evaluation of school programs should be carried out and the data fed back into the inservice program plan and design.

11. Various workshops can be held. Substance of these workshops should be focused on local problems and needs.

12. There should be professional libraries.

13. There should be professional laboratories for use in the acquaintance with materials and experiments.

14. There could be natural-science field centers; places for teachers and children to learn. (11:129-134)

The chapter on inservice education of secondary school science teachers emphasized keeping up with the times, keeping up with new professional developments, and continuing to grow in competence as a teacher and counselor of young people. There was recognition that changing educational policies require more knowledge of youth and community.

Inservice education was seen as a cooperative effort to help teachers establish themselves, continue to change and improve, and adapt to new and changing conditions. There should be means for encouraging activity, experiences in planning and group work, and concentration on selected areas such as child study or community relations. Cooperative planning and local initiative in program development, with teachers assuming the key planning role, was stressed, as was decentralization of authority. Suggested means included consultants, teachers' meetings, participation in courses and seminars, observing superior teachers, and participation in community activities. All responses were to local interests. University and state department personnel might help. Problem attacks must be specific because schools and teachers are different.

Major points, in addition to those cited for educating elementary school teachers, were these:

1. Inservice education should be locally initiated, directed to the needs of the individual teacher, cooperatively planned and carried out.

2. Certification requirements may be defined in such a manner as to encourage teachers to keep alert and to grow professionally through continued study and other professional activities.

3. Inservice education should be planned so as to develop competence of teachers in all phases of personal and professional development. It should not be narrow in conception or confine itself to purely local problems . . .

4. All available resources, local, state, and federal, should be utilized to the fullest possible extent in the inservice education of science teachers. Every effort should be made to develop in science teachers an understanding of their responsibilities as citizens and of the important contribution which they can make to society through the teaching of science.

5. Inservice teachers should be encouraged to pursue additional courses, both professional and subject matter, to insure continued growth in competence as classroom teachers. (11:275-276)

1960

In Rethinking Science Education (12), concerns for subject matter included the technological aspects of science. Accumulating knowledge of human behavior and its relationship to the nature of teaching were to be accounted for in the professional growth of science teachers. Business and industry were seen as competitors for the pool of potential science teachers so it was paramount to improve the teaching abilities of existing inservice teachers.

A better background in the nature of science teaching and planning organized science curricula were emphasized for elementary school teachers. Consultants were seen as a means of providing assistance and guidance for elementary school teachers.

Secondary school science teachers were to be provided understandings for helping students exist in a complex society, learn to think, and use knowledge in making career choices. Teachers were perceived as needing assistance in seeing a science program as part of the whole of a learner's world. Participation in inservice activities to develop these competencies was deemed necessary. Inservice education was to be continuous because science teaching must be dynamic and evolutionary in a rapidly changing society.

It pointed out that there were ample opportunities for professional growth through local committees, conferences, and workshops "if a teacher looked." Not everything has to have immediate utility and even tedious activities provide insights of potential use. Participation was considered a key to growth and growth required continuous acquisition of input with periods of rapid growth and others of no apparent gain.

New knowledge was considered important. College or university work of value was to be found in science and related disciplines, the study of the youth and their world, educational psychology, professional science education courses, curriculum and evaluation, and knowing and using resources. All such work was to be designed to respond to teachers' needs.

Scientific literature and professional literature were seen as valuable sources to those willing to use them. Activities of various governmental, industrial, philanthropic, and agency groups could also benefit teachers. Work with fellow teachers on improving instruction was seen to be of special value to the "converted" science teacher, teachers with different needs than teachers initially prepared to teach science.

A summary statement in the chapter on the professional growth of science teachers powerfully addressed the substance of inservice science teacher education:

> A profession is characterized by the nature and values of the services its members render to society. In a society characterized by its achievement in science and by a growing body of professional information, the obligation of the teacher of science to acquire professional status is clear. The hallmark of a profession is the recognized competence of its membership. As science teaching advances to professional status, the need for continuing competence becomes more critical. As individuals and as professional groups science teachers are finding ways to grow, both professionally and academically, through activities sponsored by schools, colleges, and universities, as well as by various professional and scientific societies (12:296).

Past literature does not give us a comprehensive framework, but it does suggest that the framework must consider both functions and forms. Some pieces to incorporate into a framework were: work locally, develop support systems, evaluate to aid improvement, have teachers teach teachers, do group work, do individual work, concentrate on specific topics, strive for competence, teachers don't always lead teachers, science teaching is more than teaching science.

In summary, insightful people "from the past" saw the need for and the complexity of the continuing education of science teachers. They had the capacity to identify and retain persistent needs while they examined and incorporated new societal and educational imperatives. Inservice dimensions with potential for prevention rather than correction were ever present, but there seemed to be little emphasis on developing and testing models for improving science teacher effectiveness. Discussion seems to have reflected the belief that inservice needs were tied to a teacher's academic and professional background. Much work was done on delineating the functions of inservice education but less was done with form. It "was assumed" that if functions were identified work forms would naturally develop.

FUNCTION

Because inservice education is a subset of teacher education, its basic functions are essentially those of preservice teacher education. Inservice education has two primary functions: (1) to provide knowledge and (2) to develop skills in making decisions and/or solving problems about "learning science." Decisions cannot be based solely on intuition, opinion, or old knowledge. And knowledge is of no value unless we know how to use it. We must acquire knowledge and learn to use it in many situations. Remembering that these two functions and their constant evolving interactions are the essence of teacher education makes it easier to develop and design inservice programs. Inservice approaches usually deal with only a part of the complex whole so it is helpful to look at the basic functions another way.

A Concept of Science Education

It is difficult to comprehend, but preparation in science and/or professional education does not make a science educator. A science educator is a person who thinks of continuous preparation in both science and professional education. He is an expert in the character of the intersection. He extracts pieces from each and integrates them in ways that help students learn knowledge of and applications of science in his life and the larger society. The concept of science education is constantly evolving so it must be given special attention and identification in all inservice education. It must persist to develop a teacher-scholar working at the intersection of science and education.

Academic Growth

A science teacher needs science, social science, mathematical and other knowledges absent at entry into the profession, plus additions brought about by rapid changes in a scientifically and technologically based society. Without continually upgrading academic knowledge, the base for planning or delivering an effective science program is inadequate. Content inadequacies are a limiting factor many times in a science teacher's career.

Academic growth of science teachers must be concerned with their development as citizens, as scholars in the disciplines(s), and with obtaining background at the heart of school science program(s).

Professional Growth

The many facets of teaching and learning include acquisition of teaching skills, acquisition of information about programs and materials, develomment of positive attitudes toward a total education and opportunities for self-improvement. The function includes developing skill in adopting or adapting innovations, and diagnosing and remediating learning problems based on knowledge of the subject, the learner, the teacher, the materials, and the interactions stemming from psychological, physical, emotional, and other conditions of learning environments. Here teachers develop skill in recognizing and alleviating learner problems by knowing all things that influence a learning situation. They become more adept at improving learning opportunities for students and themselves.

Personal Growth

Failure to acknowledge this dimension of teacher education may seriously dilute all other efforts. Self-concept and self-esteem are pivotal elements in being a successful teacher. A teacher who is an insecure person or who has little regard or respect for others will not provide the positive outlook, the stability, or the coordinated guidance that learners need. Content and pedagogy are like a pair of stilts. Add a full measure of personal development and there is a more stable structure. Things which cause teachers to fail often reveal a lack of security, self-confidence, or general mental health.

No teacher can facilitate learning without respect for students and self as person and learner. A teacher, fully developed as a person, can better use knowledge and decison-making skills to improve teaching.

Another Look at Functions

Because many teachers see inservice education in terms of what they do, a further look at functions is desirable.

1. A teacher must have a professional expectation to participate in inservice education, to work continuously on all functions. It is necessary for the individual to develop a concept of his role in pursuing the attributes of the ideal teacher.

2. Inservice education should create a thirst for researched and tested approaches that make productive changes, innovations. The search should stem from a concept of continuous modification and evolution with research and development activity to give integrity to local decisions.

3. Science teachers should learn why and how to employ societal need as a persistent criterion for meeting science education goals.

4. Curriculum development is a major part of inservice science teacher education. Inservice should prepare teachers to answer the question, "What is your science curriculum?," by describing the dimensions rather than stating what materials they use. Teachers need to learn to develop a local curriculum framework in the image of the big goals of science education, as a basis for determining "goodness of fit." Curriculum

work can help teachers to develop criteria for examining actions and evaluating materials and plans. Teachers need to become aware of innovations, develop techniques for examining and using innovations, and skills in implementing, institutionalizing, and maintaining sustained curriculum evolution.

5. Teachers need to learn concepts of instruction and instructional design. Skills are needed to recognize and diagnose learning difficulties; i.e., what do I need to know about science education, learners, schools, and myself to improve the learning process. We make enormous numbers of conscious and subconscious instructional decisions. A teacher must learn how to respond to and act on a system and yet to allow things to happen.

6. A critical part of inservice education is refining sensivity to the learner's needs. This requires new and more knowledge about child development and learning, physiological development, the nature of the learning process--its differential and contextual character, and the nature of a person. This is more than knowing of motivation or Piagetian stages.

7. Inservice programs must concentrate on teacher needs. Surface needs include "How do I use an aquarium to teach classification?" The real need is knowing what classification is.

8. A concept of research and skill in conducting research and development is a critical element of inservice teacher education. But it cannot be developed until teachers recognize what decision-making is and what they are expected to do. There will be "action research" when teachers see themselves as decision-makers.

There are other dimensions that could be added to "another look," but adding them is less important than recognizing that we all see functions from a personal perspective. Progress begins when entry to a situation is pertinent to the person who will receive the inservice and the individual pieces are conceived as part of the whole. Figure 1 shows how functions must be related in developing a comprehensive framework for inservice education.

FORM

In contrast to functions, what to do, form is a means of accomplishing a defined task within a specified context; the actions taken. It may be a plan for distributing information nationally, a design for learning to use inquiry in local science teaching, an idea, a strategy, or a model. But no matter what the intent of the inservice, there are many dimensions to consider in developing forms of inservice education. These include factors such as the initiating or sponsoring agencies and other key elements such as who, where and how the inservice work is accomplished.

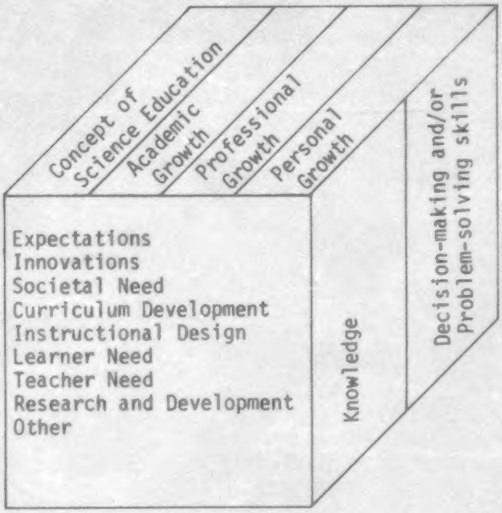
Concept of Science Education
Academic Growth
Professional Growth
Personal Growth
Expectations
Innovations
Societal Need
Curriculum Development
Instructional Design
Learner Need
Teacher Need
Research and Development
Other
Knowledge
Decision-making and/or Problem-solving skills

Figure 1: The three faces of function for inservice science teacher education.

Governmental Roles

Much inservice science teacher education, circa 1960 to the present, has been associated with governmental agencies. The U. S. Office of Education created Research and Development Centers and Regional Educational Laboratories. And the National Science Foundation has conducted several programs for educating science teachers. Activities have included research and preparation of instructional materials.

NSF efforts focused primarily on the academic and professional growth functions. Basic forms were Summer Institutes (SI), Academic Year Institutes (AYI), Cooperative College School Science Programs (CCSS), and Inservice Institutes. The most productive effort in terms of direct teacher involvement was the CCSS activity. Teachers were involved in planning, several functions of inservice education could be met, response was to the individual teacher needs.

How much impact was made by these attempts at educating large numbers of teachers with forms of inservice education not planned and developed by teachers themselves? Pertinent research findings (14) associated with teachers are:

1. Teachers did acquire more science background.

2. Institute participants continued graduate study and their mobility, especially upward, was enhanced by participation. Participants seemed to be more active professionally.

3. Attitudes toward institutes were positive but little evidence is available that attitudes toward science teaching were more positive.

4. Improvement, at least temporarily, in science teaching was identified as defined by institute organizers.

5. Better understanding of the nature of science was not necessarily transferred to improved science teaching or better attitudes toward science teaching.

6. Participants were primarily those who needed the least help.

Research results associated with student outcomes point toward

1. positive relationships (inferential) between institute participation and student achievement;

2. positive relationships between attitudes toward science and institute participation cannot be supported;

3. lack of experimental evidence that students of institute participants gained a better understanding of the nature of science.

The potential outcomes of these forms appear to have been limited by heavy concentration on the academic growth function and external directive rather than response to teacher need.

Another NSF thrust has used an approximation to a curriculum development approach for teacher education (5). In this model, teachers develop curriculum to effect change and improve teaching. In the NSF approach curriculum was not developed by local teachers. Instead teachers learned to use existing materials. Much good came of this approach but the materials often were the mode for change rather than the process. The conditions for change may be lost by not participating in the total process. But, the approach has been an advance toward teacher involvement. A disadvantage was that the teachers involved in materials development, by comparison, may have needed less help. A strength is that teachers with ideas have improved materials. Another positive outcome of this materials form of inservice education is recognition that there is more to improving science teaching than "better" materials and more teacher science background.

In the preceding paragraphs some shortcomings of externally directed efforts were identified based on limited perspectives of a complex task. Also identified were some things these forms did not accomplish. Even with the previous activities, the search for form(s) in inservice science teacher education has really just begun. But some clues for conducting the search have been generated.

1. We will not find a kit to glue together.
2. We probably cannot prescribe the ultimate form but it should be applicable to local and contextual situations.
3. Form should be based on the concepts of personal improvement and renewal. And it must have dimensions which persist to make evolutionary changes.
4. Forms designed to accomplish a task in a defined time frame should have a self-destruct mechanism. (Take the form away before it is perceived as the goal.)

Who

One of the most important questions related to form is "Who does the inservice?" Teachers are learners. Therefore, the psychological setting of inservice, including the person(s) involved, is critical. But in recent years, this key inservice ingredient has been overlooked. Teachers have been "told" that they are incapable of carrying out many teaching responsibilities. This was not always intentional but in the hurry to "overcome science teaching inadequacies," the message became "teachers are incapable of initiating and carrying out plans for self-improvement." For example, teacher-proof curriculum produced teachers heavily dependent on others for ideas and materials. Teachers need to draw on their strengths in designing and conducting inservice. They cannot be told continuously what is good and what to do.

Good inservice forms will foster teacher confidence and develop teacher recognition of others' talents. Teachers should value input from peers in the immediate environment. An atmosphere needs to be created in which teachers ask for these people resources and get people who can help them. The pulse of the inservice process is the teacher.

Science teachers should and can contribute to their peers' inservice education in many ways. Sharing materials and discussions of varying philosophies and their origins are valuable. Local teachers are particularly important in curriculum development and developing teaching skills. They can provide instant feedback to fellow teachers. Mutual planning for improvement can effect trust and respect for continuous dividends. Diagnostic work can occur and remedies be put to work immediately. Local people are the heart of improvement. Therefore, good forms of inservice should include a plan for teachers teaching teachers.

Other "who's" include community groups, college and university personnel, teachers in other districts, professional organizations, governmental agencies, businesses, and industries. A major problem is identifying what a group has to contribute and who from the group has the necessary expertise, insight, and personal characteristics to make a contribution. Some persons are good at practical application and others are good at conceptual and theoretical levels.

A critical criterion in developing inservice form is matching who's with the desired assistance. A constant error in planning inservice education is to ask a "group" for something they cannot deliver or to expect everything from the same group. Everybody loses. There should be an internal needs analysis to determine where along the theory-practice continuum the need lies. This assessment helps determine "Who does the inservice?"

Professional organizations can assist with "awareness" and aid skill development with guidelines and criteria for good performance. Governmental agencies can provide awareness, help establish goals and standards and foster research and development.

There are many "who's" to deliver pieces, but the impact is determined by the individual recipient's response. Everyone who can help a teacher help himself should be involved. Whoever can provide means and opportunities should be asked to participate when the match is right, especially teachers and their groups.

Where

An inservice site also has substantial bearing on the psychological state of the participants; it affects who responds and in what ways. Site selection must be done carefully in planning inservice forms. It makes a difference whether a session on classroom management strategies is to make teachers aware of ways to improve or to develop skill in using strategies. If the intent is awareness, the site may be less important, but if the intent is developing skills, a site for real testing must be picked. Inservice activity is oriented to "my" situation and problems, so it should be in my situation whenever possible.

Site selection should consider science education goals, characteristics of all participants, and goals for the current inservice. The planned purpose must be known in advance by all parties and the site selected accordingly. A site must be chosen so the teacher's participation can effect personal payoff. All activities have a functional dependence so every participant should work in an area conducive to getting a job done. If everyone knows the task and agrees that the site is "right," things can proceed in the agreed upon direction. A site cannot go beyond its capability.

How

Much current inservice education is founded on the "training" concept. There are important training elements in the inservice process but training activities must be treated as a means, not an end. Teachers are trained to do many things without "knowing" the purpose. Thus, if outcomes are unsuccessful, there are no criteria for identifying source(s) of failure. More attention was given to the training package than to the idea behind it; more training will have to follow. We learn by doing and thinking about what we are doing.

"How" must stem from the conceptual bases of science education and be keyed to functions of inservice science teacher education. Functions are a major part of the accountability system. They are the source of (1) competencies which deal with ideas and goals and (2) competencies which deal with specific skills.

The first step is to identify which inservice elements to pursue and then select appropriate "hows." Some general considerations in determining the HOW element of inservice forms include these:

1. Identify and clarify functions to be served in the local context that are accountable to global needs.
2. Have the individuals to be served involved from the beginning. Every individual should believe that the activities are a response to his plan.
3. Design activities to increase teacher independence.
4. Separate inservice education from the college credit syndrome.
5. Tie inservice education to certification. Certification requirements should expect teachers to keep proficient in ideas and skills.
6. "How" should revolve around students. Success of inservice strategies should be based on improved student learning during periods following inservice.
7. "How" should be oriented toward competence in effecting learning.
8. "How" should be in response to requests for help. Some inservice can be accomplished by disseminating information, knowledge, ideas, and approaches, but the ultimate value is in a design to solve an existing problem.
9. "How" should keep teachers constantly aware of new knowledge and decision-making possibilities.
10. "How" should be a mechanism whereby teachers determine what they need.
11. "How" should have a short range and a long range plan for measuring change.

In addition to the above considerations, forms of inservice education need to aid teachers to move from knowing of means for improvement to making a change for the better. The major categories in this cyclic continuum are:

1. awareness
2. introductory exposure
3. implementation
4. institutionalization
5. modification and evolution

Some forms to accomplish these purposes include graduate study, redefining certification requirements, specifying competencies related to learning, working in school situations, classroom visitations, and other forms such as teacher centers, institutes, drive-in conferences, workshops, and implementation programs. Further thoughts on form follow:

1. Highly productive forms focus on the individual in the classroom; the goal is doing what is necessary to cause change. Classroom activity permits obtaining data for making contextual and current decisions. Inadequacies can be diagnosed and remedies can begin. This is the ultimate because existing knowledge can be applied. If it doesn't work there wasn't enough knowledge or ability to use the knowledge.

2. Graduate education should create an expectation to keep adding to the knowledge base for decision-making, and should use the theoretical bases and new knowledge from research and development. It has awareness potential and deals with potential rather than with guarantees. Graduate education concerns itself with the whole of teaching that includes but goes beyond meeting immediate personal needs.

3. Institutes are useful when the substance is created by those to receive the inservice. Some benefits accrue from institutes required by law or devised by others, but they operate from the mass therapy model which depends on much hope. Institutes have potential for awareness, initial exposure, cues to implementation, and knowledge about success in other situations.

4. Drive-in conferences can contribute to awareness. They permit making contacts, sharing, identifying common problems, becoming aware of other's successes; all valuable bits. Participants come because they want what is offered.

5. Journals and conventions are potent devices for distributing knowledge and information. They can be used for awareness, initial exposure, and clues to implementation. The potential of these forms is

in promoting the highest ideals for innovation and change as the criterion for being a good science teacher.

The convention form might be strengthened by eliminating some paper sessions and bringing people with needs and talents together to discuss and plan innovation and change. Identifying a topic and providing a discussion site would be welcomed by many who seek ways to improve their teaching.

6. Books and newsletters are also good mediums for conveying information and describing approaches for improvement. They are especially useful in describing useful structures and conditions under which other teachers have been successful.

The above forms depend heavily on making current information of subject fields, learning, etc. and materials available to help teachers innovate and make change. These forms have some obvious weaknesses but are necessary to the overall plan.

EXAMPLES OF GOOD PRACTICE

Research Participation

Research participation was one form of early NSF Institute. This approach assumed that knowing how to conduct independent scientific research would foster student inquiry. But becoming a good laboratory scientist does not guarantee improved teaching.

The concept of research participation is sound, however, if it focuses on processes of teaching and learning by involving teachers in conducting research. Recently a class of junior high school science teachers studying problems and issues conducted studies with their students. They were shocked to find that their students did not understand classification; a major impediment to a program that included many classificatory science concepts. They also found that few fifth and sixth grade students viewed graphing as communication. These studies were helpful because the teachers saw that their science knwwledge was of limited value unless they knew how to use it. If problems were identified and teachers and other science educators worked on longitudinal studies, research participation could pay off.

Research participation is an excellent form for diagnosing teaching deficiencies and developing plans for gaining competencies. An ongoing local research and development program would provide the "laboratory" we subscribe to. Teacher needs emanating from this process could be the impetus for all in-service education. Most of us think in terms of what we experience, observe, and handle. We learn more efficiently when we can work with examples and non-examples.

Teacher Centers Here and Abroad

Another promising form of inservice teacher education is the teacher center because it is a means of achieving balance between teachers' actual needs and what groups such as organizations and governmental agencies perceive as needs. Evidence of their potential power is their world-wide appearance.

The center concept is not a recent development. When initiated, "someone else" had answers and solved problems and teachers were seldom involved in planning and program development. Today's centers provide information teachers need and want, provide variety in response to diverse needs, and use the "outside expert" for perspective. Cooperation and recognition that teachers can educate teachers are major dimensions. Teachers design centers and make them work. New thoughts and national concerns are available for sampling. Local and personal funds are utilized to strengthen commitment. Today's centers are teacher creations, a means for personal improvement.

DeVault (3) reported on teacher centers in Japan, England, and the United States. Impetus for these centers came from teachers and organizations and agencies, including the national government and local educational agencies. However, the character of the center and its programs is heavily governed by teacher needs.

Japan.

Points of note about Japanese centers are: (1) a belief that professional growth is continuing education, (2) teachers are expected to engage in professional growth, usually without salary increments, and (3) the national government has placed a high priority on inservice education.

Specific comments about each of several centers are worth noting here.

Tokyo Metropolitan Institute for Educational Research and Inservice Training

1. Research and inservice training are closely linked.
2. Activities focus on specific topics and projects such as "Inquiry Process Oriented Science Instruction."
3. Center activities result in the development of educational materials associated with a theme which are distributed through teacher participation in center activities; users provide feedback.
4. Programs include field work, regular classes, once-a-week programs, Saturday programs, and academic programs.
5. Staff members engage in teaching and research.

Osaka Science Education Institute

1. Participants are relieved of classroom duties to attend meetings.
2. The focus is on teachers with two to five years' experience--enough classroom work to recognize specifically where they need additional training and assistance.
3. There is a special section for investigating special problems of school education.

Kyoto Science Center for Youth

1. Study groups respond to teacher need.
2. Inservice comes through working with youth.
3. Activities concentrate on respective schools.
4. Staff include teachers who serve for three to four years in many capacities and then return to their respective schools.
5. Staff includes scientists and science educators.

The Science Department of the Chiba Prefecture Education Center

1. Studies and investigations of the content of inservice courses.
2. Offer expert advice on a variety of matters.
3. Disseminate data and information on science education.

All the Japanese Centers have key characteristics. They are staffed by residents and teachers on limited term assignments. They concentrate on highly specialized teacher needs, and the program evolves with teachers at the focal point. Work revolves around ideas and specific directions and materials are not forced on the teacher.

England. The Nuffield Foundation played a role in the creation of English Teacher Centers because local teachers needed a mechanism for communicating and trying out materials. But the centers are closely associated with local educational agencies; funding is largely local, and the program has a local flavor. Most centers combine two or more of five activities:

1. The social-pastoral.
2. The focus and resource for inservice courses, workshops, and discussion groups.

3. The convenient and neutral venue for meetings, exhibitions and local survey or report writing groups.

4. The resource center including (a) availability of information about courses, curriculum development projects, educational publication, (b) advice and assistance in reprographic and educational technology, and (c) loan facilities in equipment and resource materials.

5. The centre for curriculum development groups.

Burton-upon-Trent

1. Major foci are curriculum development and inservice training.

2. Several teachers work on a part-time or a short-term basis.

Barney Royd

1. The director exerts "firm but unobtrusive guidance."

2. Teachers can "combine professional studies with opportunities for social contact."

3. A managing body receives recommendations for studies from anyone; once accepted, a panel plans program.

City of Bath Teacher's Centre

1. A response to a felt need for a forum.

2. The main function lies with curriculum innovation and development.

3. Offerings of colleges and other peripheral groups are valuable only because they are nourished and sustained by the ideas and the experiences of the grassroot professional.

4. The center responds primarily to personal needs; the LEA can provide courses pertinent to the schools.

United States. As in England and Japan, U. S. teacher centers concentrate on solving the individual teacher's problems no matter how small or mundane, so they do not destroy the teacher's capacity to perceive the big picture. They emphasize linking preservice and inservice, and productive use of teacher energy. The many kinds include:

1. independent centers (tea centers)
2. staff development centers (establishment centers)
3. consortium centers (cooperating centers)
4. exemplary material and experience centers
5. installation centers
6. creativity centers
7. regional training centers
8. field intern centers
9. lighthouse centers
10. concept centers
11. combination centers
12. other centers

As one example, the Appalachian State University Training Complex uses many consultants and resource people, employs the "model school" strategy, develops mechanisms from plans based on expressed need, involves preparation of teacher trainers and college students, and pays to release teachers so they can use the center.

The Greater Boston Teacher's Center, and its several localized, offshoot centers, uses the continuing help approach. Activities concentrate on (1) increasing teachers' self-confidence, knowledge, and ability to deal with classroom problems of instruction and management, and (2) extending the use of existing parent, teacher, and community resources toward improved schooling. Center users personally pay for many activities and workshops, and if college credit is given, fees go up markedly. Special contracts for selected services are sometimes written. Advice is given freely, and the center provides some assistance no matter what help is sought.

Other "teacher centers" range from meetings in teachers' homes to elaborate networks, but they all respond to special needs and help teachers with their problems.

Butts (2) provided a description of an operational U. S. teacher center for science education. Of note is the strong emphasis on the prospective teacher even as referral is made to teacher renewal. And it can be inferred that this center is as motivated by external influences (use competency-based teacher education; disseminate curricula) as it is by a desire to respond to individual teacher needs. However, the center has many possibilities for inservice education. A strength of the organization model is the school-university interplay, both groups making the learner the focal point.

Preservice Education

This form can be a part of any field-based, preservice teacher education program. It could contribute much to all teacher education if appropriate emphasis were given to the continuing education dimension of teacher education. Unfortunately, inservice teachers' needs are rarely identified and thus a highly desirable, symbiotic relationship is thwarted. A program with the potential for making the above transition in thought is described by Ring (13). He described a cooperative program for preparing new teachers. If the inservice education needs were identified and the program modified to place inservice needs on a parity with preservice needs, all participants would probably derive more benefits.

The key to teacher education is people. All forms have their highest potential when they serve the individual because there must be a feeling of personal involvement, a response to need, and opportunities for success from the beginning. Two things characterize the better forms. Theoretical and practical elements together fuse basic and applied dimensions of education and no matter when or how one enters the cycle, professional growth is possible.

MODELS

Individual pieces of inservice education take us further when they are part of a comprehensive framework or model continuously tested. Models can guide activities and help refine the inservice process. But the amount of thought given to model development has been extremely limited. Even those who espouse models have not put "the pieces" together. Responses to the immediate press ("make 'em aware," "hands-on") have neglected the long range. Lately, however, there are signs that we are less now-oriented and are seeking broader models. What follows describes some promising work on models.

Awareness and Interest

Horn (6) proposes a means for distributing information to widely dispersed teachers. Absence of a figural representation of the concept makes it difficult to visualize the model, but a regional site is a nerve center for evaluation, research, instruction, curriculum development, and serves as a resource bank. The approach uses a response mode. Staff serve in an instructional capacity, conduct needs assessments based on teacher contacts, make long-range plans, and serve in an assistance role. Support comes from those who use the center.

Limitations of the approach are: (1) what people say are "needs" are not necessarily needs and (2) providing familiarity doesn't necessarily promote change. But teachers should feel good about what they do and a center can facilitate many inservice tasks.

Several "modeling" approaches have been associated with course content improvement projects. They include a local environment situation, a state network, and a national endeavor. Each attempts to relate the several functions of inservice science teacher education.

A Local Approach

A program for improving local earth science instruction (8) has several strengths: (1) interrelating two major functions of education, (2) change takes time, and (3) materials illustrate ideas.

Summer '69	1969-70	Summer '70
Workshop	Pilot classes Observations Seminars Feedback	Summer course Feedback
1970-71	Summer '71 1971-72	Spring '72
School implementation Feedback	Continuation activity	Final evaluation

Figure 2: Organization plan for inservice program.

An initial summer focused on understanding earth science concepts and using investigatory approaches in science teaching. Then, teachers began the year. They used new knowledge and they observed peers using up-to-date prototypic materials. Teachers of ESCP pilot classes and other teachers met regularly to analyze progress.

A second summer revolved around acquiring earth science content and developing inquiry based earth science curricula. Now participants "knew" what they needed, and the inservice staff, especially teaching peers, could respond. Questions dealt with the fusion of content and science teaching; they are inseparable. Good ESCP was combined with other good science teaching. Development activity was personal and useful locally. Approaches blended good thought about earth science teaching, science teaching, and the teaching styles of individuals and groups. Good materials were used to get at good thought. Teachers improved their concept of science education and dealt directly with academic growth and professional growth. And they could grow personally because of non-forced working relationships.

Implementation followed development. Tapes helped analyze teaching and monthly meetings helped analyze the total picture. Helping an individual develop a team concept for evolutionary program development and refinement by combining new thought with local conditions was emphasized. The following questions are raised to suggest expanding a good approach into a more potent change force.

1. Where is teacher assistance when the glow fades?

2. Only earth science teachers were involved. What happens to students if there is not a plan for all science?

3. Initial stimulus "came from external sources." What plan was made by the local teachers to achieve independence?

A State Approach

In Iowa, a statewide network (Project ASSIST) distributes information and provides implementation support for course content improvement projects (14).* But the organizational and the conceptual models have promise even if there weren't any projects. The project title is highly appropriate.

All major groups concerned with improving science teaching participated in developing this response to grass roots needs. Administrators and science teachers are involved and staff includes local supervisors, key teachers, curriculum representatives, and professors from several universities. Figure 3 shows the organizational structure of project ASSIST.

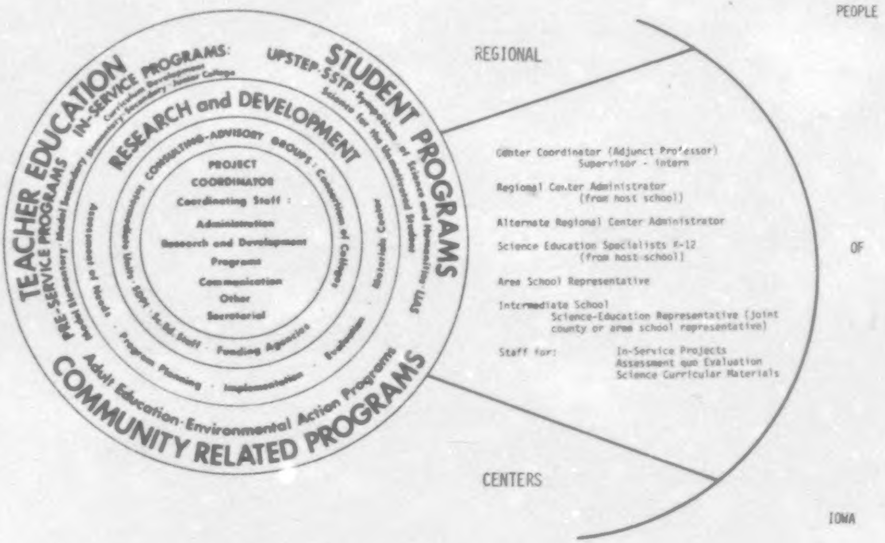
TEACHER EDUCATION
IN-SERVICE PROGRAMS:
Curriculum Development
Elementary · Secondary · Junior College
PRE-SERVICE PROGRAMS
Model Elementary · Model Secondary
STUDENT PROGRAMS
UPSTEP · SSTP · Symposium of Science and Humanities · LLL
Science for the Unmotivated Student
RESEARCH and DEVELOPMENT
CONSULTING-ADVISORY GROUPS · Consortium of Colleges
Materials Center
Evaluation
Implementation
Program Planning
Assessment of Needs
Intermediate Units · SDPI · Sc. Ed. Staff · Funding Agencies
PROJECT
COORDINATOR
Coordinating Staff :
Administration
Research and Development
Programs
Communication
Other
Secretarial
COMMUNITY RELATED PROGRAMS
Adult Education · Environmental Action Programs
REGIONAL
CENTERS
PEOPLE
OF
IOWA
Center Coordinator (Adjunct Professor)
Supervisor - intern
Regional Center Administrator
(from host school)
Alternate Regional Center Administrator
Science Education Specialists K-12
(from host school)
Area School Representative
Intermediate School
Science-Education Representative (joint county or area school representative)
Staff for:
In-Service Projects
Assessment and Evaluation
Science Curricular Materials

Figure 3. Organizational structure of Project ASSIST.

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*Information about ASSIST came primarily from working papers and brochures obtained from the project staff at the University of Iowa. A brief description of some aspects is available in Sharp, 1975.

Local meetings to consider adoption follow awareness conferences. If teachers "adopt," they are invited to participate in a program at a regional center. Subsequent classroom activities are supported with inservice meetings, school intervisitations, staff visits, and meetings at individual schools. This organizational model allows for long range continuation.

Valuable dimensions of this model are coordination, regional involvement, cooperative needs assessment and curriculum and program development, self sustaining program development, and a materials center. Project personnel see the strengths to be:

1. measuring and assessing regional needs;
2. identifying and priority ranking deficiencies;
3. setting minimum acceptable standards for solutions;
4. specifying desired outcomes;
5. searching for alternative methods to achieve desired outcomes;
6. choosing the most promising acceptable methods;
7. organizing and implementing program; and
8. evaluating results of new program.

Other State Responses

Multiplier approaches are attractive for awareness and initial acquaintance with programs and materials. The Illinois Office of Education and the Illinois Science Teachers Association have sponsored Awareness Seminars where teachers learn of new programs, taste-test the wares, and identify sources of knowledge and assistance.* Change is encouraged by proving opportunities for people to get together. Specific efforts at skill development are left to the teachers and their inservice mechanisms. In Florida (15) specific workshops are conducted to train teachers to teach teachers. In both instances, as much as possible is done to respond to teachers' needs.

Multiplier programs may suffer from dilution. Initially there are dual benefits of awareness and education but each successive stage has the potential of decreasing the effectiveness. However, more people become aware and teachers' aiding teachers' pays huge dividends.

A National Model

A larger scale model is the dissemination and implementation approach for Unified Science and Mathematics for Elementary Schools (USMES), Newton, Massachusetts.** The approach has all the limitations of inservice for a single program but its strengths are compatible with desired features of models for inservice science teacher education.

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* For additional information, contact the Illinois Office of Education, Springfield, Illinois.

** For additional information, contact the USMES Implementation Section, Educational Development Corporation, Newton, Massachusetts.

Resource teams are prepared, *many* of whom are classroom teachers. Each team adds new members and prepares new teams. These teams serve their own needs and they can respond to other's requests for inservice. Local people know who knows something of their problems. Team members have commitment to the program philosophy and participate by choice. Each teacher gives and takes what he can and uses what he can, as long as he can. The inservice program emphasizes working with those who have a commitment, assisting them to develop at their own pace. In theory, this form distributes knowledge and skills rapidly across large areas.

Team members are "experts" because of their knowledge and skills, not because of their institutional affiliation. Teachers' needs are met by people they see as equals. Outside experts are used when there is a lack of local expertise or when a special presentation is desired.

An Advisory Approach

For the long haul, we would be well advised to adopt the advisory approach described by Katz, et al (7). This "model" is based on four fundamental premises:

1. Inservice is to come from within; when teachers perceive a need and ask for help, then provide assistance.
2. The basis for assistance should be the goals, objectives, needs, etc., of those who asked for help.
3. The assistance should be provided *in situ* rather than in courses, institutes, or seminars.
4. The assistance should be provided in a way which will increase the probability that the teachers will become more resourceful and independent of outside sources for their every need.

The approach runs contrary to much recent inservice because it is not directive nor focused on specific materials. But it acknowledges that the primary goal of inservice education is to help *a* teacher improve teaching. It works with the individual teacher who continuously plans and designs *his*/*her* inservice program.

A personal experience with SCIS shows that this approach is also useful in implementing programs. Local teachers first *asked for* awareness, then initial implementation, and implementation help midway through the first year. Teachers identified needs and planned how to meet them. Both teachers and consultant felt good about what happened. The teachers made a commitment to help themselves improve their science teaching.

In Retrospect

What light does discussion of functions, forms, models, etc, shed on inservice science teacher education? For one thing there is confusion. We sense teacher needs but are not sure how to respond. Needs assessment approaches and techniques, in general, are not well developed, and ways to respond to needs are just beginning to be formulated. What we might have thought to be a relatively simple task becomes ever more complex, because we have no comprehensive framework derived from the premise of improving teaching. Some organizational plans can help, but teaching improvement is too often done through an intermediary such as instructional materials.

What is beginning to surface in many current approaches, which is excellent, is to do more to help teachers help themselves, and to help other teachers. (A vision from the past?) The described attempts and other related pieces being tried are beginning to give us insights into elements of a needed comprehensive framework, a framework to guide innovative, change-oriented forms of inservice education which consider all functions.

THE FUTURE

The future of inservice science teacher education is bright. Older solid ideas are being fused with newer ideals to continue an evolutionary process. Things are changing and the future is going to be good.

Science Education

The foreseeable future will be a period of searching. Our current concept of science education is not sufficiently resilient to tolerate stresses. For example, developments such as environmental education tend to replace or divert science education. Environmental education is not science education, but its goals definitely overlap science education goals, especially, learning how to acquire and use knowledge to solve problems.

A comprehensive concept of science education will relate to environmental education, career education, values education, and technology education in a logical and integrated fashion. Good science education will be all these things; neither replaced nor diluted by "newcomers." A major future task is to create, in all science teachers, a forward-looking concept of science education; a concept based on cognitive and affective considerations. Teachers who develop that concept can continue to grow professionally.

Inservice Science Teacher Education

Function and Form. Some comments about the future of function and form are in order. In terms of function, we need:

1. broadened definition of teaching which includes personal expectations for inservice education--through research, program development, self-evaluation, and seeking change as a constant.

2. expectations and role definitions for all the parties who might contribute to the education of science teachers, especially other science teachers.

3. a concept of inservice science teacher education based on helping rather than directing.

4. a re-examination of roles for governmental and state agencies in teacher education, especially the conflict between the R & D concept generating new knowledge about effective forms, and being a marketing institution.

5. a re-examination of the purposes of professional organizations such as AETS to see whether, in fact, they are pursuing ideals which will allow for change to occur or whether they busily engaged in the pursuit of things which really don't make a difference.

As far as form is concerned, we need:

1. a concept of form based on meeting ideal science education goals through a response to individual teacher needs

2. forms, ultimately models, which include
   mechanisms for needs assessment,
   response to individual teacher needs,
   working with teachers in their classrooms

3. many forms to accomplish specific purposes

4. academic growth and professional growth specific to needs.

These last comments do not exhaust the possibilities for a list of future needs. But they do emphasize that we are at a point where we would be well advised to look carefully at what we are doing. Are we really doing anything worthwhile or are we just playing games with outselves and others? It is difficult to answer such a question, but it must be asked.

The other point is that the key to inservice science teacher education is the individual teacher. His or her needs must be met in order for change to occur. Anything which detracts from responding directly to that individual's needs is potentially less effective.

Some broad expectations. Future inservice activity will have less financial backing. Of necessity local and regional resources, monetary and personnel, will be tapped. I look to this "dilemma" with delight. People with ideas and talents to innovate and effect change will no longer be overshadowed by big money and a materials warehouse. Forms of inservice science teacher education that bring teachers together to work on teacher problems will receive their appropriate due. We will de-emphasize "causing" improved science teaching and develop means that allow change to occur. Recognition will be given to root causes rather than symptoms such as "the dearth of good materials."

I suggest we adopt a philosophy of teacher education based on the following:

> What education does, as a social change agent (in the long run), is let loose forces that produce their own effect in and on society, and those effects can be neither prescribed, predetermined, predicted, or prevented. They will be whatever future man, thinking for himself, decides they will be. For "thinking" implies nothing foreseeable about conclusions it may lead to. Hence, when unthinking people genuflect piously toward the Ability To Think as the high aim of education, they seem unaware of its meaning (as it does mean) that two persons, pursuing equally valid lines of reasoning from the same starting point, may arrive at quite disparate end positions. To teach and encourage students to think for themselves is therefore to entertain the lively possibility that they may reject some of our cherished preconceptions in favor of their own variety of alien corn. We can't have it both ways; educate and at the same time keep the educand from having ideas of his own (1:17).

Science teachers have their own ideas. We won't change those ideas by clinging to the past. Rather than tell teachers what they *must do* and how to do it, our future should emphasize what we would like to do and what we might do to help get there. Basic functions of teacher education will be used to help determine whether an evolving process is taking us anywhere and how well. We will *guide*, not direct, and the guidance will be based on a commitment to long range goal attainment through personnel development.

When science education goals and inservice functions are examined simultaneously the use of forms can attempt to improve a situation. Fundamental goals and functions change little with time. What changes are the teachers interpreting and working toward goals. Thus, the forms must be varied because of the variability in teachers' needs. Each teacher has to be dealt with differently from those who came before and from each other. At a given moment some function(s) will receive preference because those to be helped see the situation from that frame. Identify a receptive point of entry and progress will be made. Science educators who have the patience to make change in small increments based on solid foundations are coming to the fore. Surface impediments such as "no implementation money" won't stop them. These teachers will help those willing to help themselves.

In future inservice activities teachers will learn to make decisions, ask pertinent questions, and recognize the source of problems. For example, a distributor of printed materials says that the readability of science materials has been improved. A teacher will ask whether this was accomplished by changing sentence length or selecting concepts consistent with students' thinking abilities. Such teachers will decide what to eliminate, modify, or add to maintain an evolving curriculum. And these teachers will identify program limitations. They will ask what goes when this is added and ask whether that thing is an old chair with a different cover. They will respond to student needs and measure their effectiveness in terms of student learning.

Competency-based (performance-based) teacher education will be developed for inservice work because state agencies, districts, and teacher groups will insist that competence be demonstrated by verifying that students are learning. Inservice education will stress knowing those things needed to help students learn. Teachers will have to develop competence in all functions of inservice science teacher education. For example, in Minnesota, teacher certification requires competence in subject matter as well as pedagogy. There are many competencies but we come to recognize that no one set of competencies guarantees success for a teacher.

Competencies have been observed in situations where there was good teaching. Thus, they become a means of indicating which knowledges and skills have been productive in effecting student learning. The concept should prove effective where competencies are used to guide teachers toward things to help student learning. Identified competencies will be used to create expectations for all concerned with improving science teaching. We will examine teacher behaviors in student-teacher interactive situations and engage in research and development associated with student learning. This will be inservice science teacher education.

We should also see recognition that an "innovation," either ideas or materials, is not an innovation until it has an impact on teachers and students. In other words ESS and CHEMS are not innovations unless they promote local change. The notion of innovations for the local context is germinating. Many science teachers are going beyond projects and materials to problem causes. Their ideas grow steadily in potency and the numbers of people being educated by these teachers should grow rapidly. It is tremendously exciting.

Future inservice activity will give us some real innovations. These will include ideas of what teacher education really is, models for converting ideas into practice, ways to develop materials that are responsive to good thought and local needs, and ways to give form to continuous, evolutionary inservice science teacher education. Our future is going to bring us a belief in the strength of teacher to teacher interactions.

We'll also make sense of "accountability." Accountability can be measured only in terms of student learning. Rather than using programs to determine teaching effectiveness, teacher effectiveness will be judged in terms of continued student learning. Effectiveness of the inservice science teacher education will be judged by the same criterion. Work will concentrate on teacher and student-teacher interactions to produce better student learning. We will see the true value of competency--not what we think a teacher should be able to do before working with students but what teacher actions produce results under certain conditions. What competencies can I acquire to improve my teaching? We will see in-school research and development based on constant diagnosis of learning. Inservice education will provide teachers with support systems to help them develop competencies. People with the concept of accountability will transform it into forms and management schemes to get the job done and eliminate some of the triviality.

We will also see that good inservice education comes when working with the person. Respond to situational needs and guide the accumulation of responses toward the highest ideals of science education. Supportive research and guiding models are coming. Enough of the big picture is formulated and enough of the pieces developed that some major breakthroughs can be expected. These breakthroughs will be responses to people and solid ideas. We will not be as easily sidetracked by such notions as teacher-proof materials.

Future inservice education will decentralize. Centralized efforts may create and test ideas but the action will be in the local setting. Future forms of inservice science teacher education will concentrate on working with teachers rather than having teachers learn to use specific materials. Development of innovative ideas and techniques will be emphasized rather than materials "to cause" innovation. When materials are developed or selected in response to local needs they will be innovative. The strength of this approach is already evident in developments such as teacher centers.

One of the most exciting features of future inservice science teachers will be the problem solving aprroach. Expectations for student learning (desired and possible) will be specified and means of assessing progress toward those goals will be established. If the expectations are not being met remediation will be necessary. This means that the teachers responsible for facilitating learning need to improve their competency to effect learning. The emphasis will be on helping teachers determine what skills they could develop to get the job done. THEN, we have inservice education.

We're going to be more adept at inservice science teacher education because we are going to transfer general research on teacher education to science teaching and we're going to identify the unique aspects of science teaching so they can be researched. We'll use experimental studies, but teachers will combine them with personal action research plans. We use the best of all research. All teachers will be "researchers" and their research efforts will be where teaching and learning take place. The future is bright.

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CHAPTER 4

SCIENCE SUPERVISION: FORM AND FUNCTION

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Many elementary and secondary school teachers who might read this book and having intimate knowledge of the prevailing conditions in schools may be prone to ask "What is the supervisor going to supervise?" The obvious answer from many science educators will be "science instruction, of course."

Is Science Being Taught?

The answer is not as final as one might presume it to be. Is science truly a part of the instructional program in our schools today? Do teachers make an honest effort to provide instruction in science? At the secondary school level the answer is readily affirmative. Science is scheduled for specific time blocks. It is probably true that science at the secondary level has been legislated or dictated by state officials into the curriculum. Consequently, most secondary schools require science in the middle school and a laboratory science of all students in the senior high school. The requirement seems to be satisfied most frequently by having students enroll in a biology course at the ninth or tenth grade. However, one must wonder what is really happening in the secondary school science programs in view of the reported decreasing enrollments in some of the upper level secondary school science courses.

In too many elementary schools science is not an integral part of the school program at all and is not being taught. Why should there be a supervisor for a subject which appears to be considered, by the classroom teacher and the administrators responsible for the instructional program, less important or less rewarding to the student? Evidently there is a perceived hierarchy of subject importance in schools, and science is in a position of lower priority. Too many elementary school teachers readily acknowledge that they do not teach science or teach it only when they think they have time. If a subject has to be scratched from the program, it is science. Even in schools where materials-oriented programs have been adopted and provide much interest for the students too many elementary school teachers "cop-out" on their responsibility and do not teach the subject as a meaningful part of the school program. It certainly seems that one of the functions of a science supervisor should be to raise the priority level of science so that it is taught as conscientiously as any other subject.

Some Symptoms

There are continuing reports in the press about the American students' inferior skills in science when compared with students in other countries. A most recent report indicates that Vietnamese children are on the average two to three years ahead of U. S. school children and have much better backgrounds in mathematics and science at the lower grades (14).

Limited reports from sales representatives reveal that, because of economy reasons, science is being removed from the curriculum in the primary grades and not included in the program of studies until grade four. Why science? Is science the least rewarding subject in terms of student interest and child development?

Is this apparently negative attitude toward science due, in part at least, to the extensive cognitive and management demands such a subject places upon the teacher? Is this attitude also due to the lack of a capable colleague who can effectively assist the classroom teacher in finding adequate solutions to problems arising from those far-ranging demands? Possibly. Is science taught on a more regular schedule in the elementary school in those school districts in which a science supervisor is employed when compared with those districts in which there is no science supervisor? If research data indicate that the answer to this question is positive, then a science supervisor is, indeed, a necessary staff member in a school district.

What about the science supervisor at the state level? Reports from supervisors in some states reveal rather distressing developments for those who look to the state level for leadership. Due to budgetary limitations in some states all assistance for personal visits to the local district level has been cancelled. Assistance can be offered by telephone and written communications or visits by district personnel to the state office but the state personnel cannot visit the local level. It is true that the financial exigency has also curtailed the consulting activities of supervisors in other disciplines. This, however, provides no salvation for the school district personnel who are seeking assistance with the pressing problems of the science program.

Origin of the Science Supervisor

A review of the literature provides little insight into the position of the science supervisor. It is almost impossible to find answers as to how and why the position was established in school districts, or what unique criteria were established for those who would fulfill the position.

It seems that supervision was traditionally considered to be the responsibility of the principal or some other person in authority in the school hierarchy. The primary responsibility of the authority figure was to observe the performance of teachers, arbitrarily decide whether such observations should be discussed, and infrequently convey information about new practices and materials available to the classroom teacher. The limited role of the supervisor was well-defined in those schools that were administration-dominated and hierarchically conceived. The principal-supervisor was "the boss" of the building and the teachers, and the teachers were "the bosses" of the children. The chain of command with associated duties and freedoms was well established. Few dared to test the authority or seek meaningful assistance to improve the teaching-learning environment.

Although the position of science supervisor was found at the state level and in some tables of organizations at the local level prior to Sputnik, events at the national level provided the impetus for the establishment or/and rapid expansion of the position at both the state level and local levels.

The National Defense Education Act, with the provisions of Title III, required that someone with more than a superficial knowledge of science be employed to write proposals and requests for funds and then to evaluate the expenditure of NDEA funds in order to comply with the reporting procedures.

The number of science supervisors at the state level increased significantly with the expansion of NDEA, Title III. This legislation enabled state departments of education to assist schools in defraying the cost of equipment needed to initiate and/or expand existing science programs. Schools were also aided in defraying the costs of remodeling existing science facilities. Other provisions of the NDEA provided funds to (1) allow the school district to offer instructional programs in science and mathematics in order to improve the subject matter competency of the elementary and secondary school teachers, and (2) to purchase equipment and supplies in order to enable the science program to include laboratory experiences. The development of programs of instruction and the ordering of materials demanded a skill and leadership not previously deemed necessary by most school districts. It should be noted that administration of the Act was left to the discretion of each state. Thus a wide variety of programs and procedures resulted.

This flexibility enabled each state to establish its own job specifications for the position of science supervisor. In most instances, success as a classroom teacher at the secondary school level and subject matter depth were the primary criteria sought in filling the positions. It does appear that state level science supervisors, because of the variances in professional preparation, filled their positions in a variety of ways. Since NDEA funds were sought by local districts, many supervisors devoted their major effort to disseminating information to local schools either by direct mailings or through country or regional offices. After local school districts had identified their particular needs; a proposal and request for funds was developed, consistent with NDEA requirements, and submitted to the state office where the merits of such a request were evaluated and decisions made on reimbursable items.

A second type of responsibility exemplified by the state supervisor was found in instructional programs. Large trucks were equipped as science laboratories and engaged for extended periods by school districts. Usually the district had particular needs for inservice instruction, and the state science supervisor was then able to provide instruction through a hands-on experience. The emphasis usually focused on new programs and new equipment which, hopefully, would be purchased by the district to improve existing conditions of instruction.

A third form of supervision at the state level was designed to enable the supervisor to work directly with the local district in planning, evaluating, and developing the total science program. The premise for this approach was that program, equipment and facilities had to be compatible and planned in-toto. This was a particularly important service during the 1960's because the rapidly expanding school population required extensive facility development. The method deemed best to implement this type of consultant program was to meet with teachers and administrators in their own schools. The personal visits enabled the supervisor to ascertain the appropriateness of such requests and determine whether the proposed program could be developed with the competency of the local staff.

In summary, those science supervisors at the district level whose positions resulted from the demands placed upon state departments of education appeared to have four major responsibilities:

1. Provide leadership for curriculum organization and development.
2. Serve as a resource person on curriculum materials.
3. Organize programs of instruction for inservice teachers.
4. Establish lines of communication between the state and local level.

During the 1950's and 1960's the rapidly expanding school population placed additional demands upon school districts. This rapid increase in the number of teachers, coupled with the demands of federally-supported programs, created the need for additional vision of the science programs at both the secondary and elementary levels.

Through the leadership and financial assistance of the National Science Foundation, private foundations, large corporations and in later years the U. S. Office of Education, a variety of programs were developed to provide assistance for the classroom teacher. Some of these programs provided direct assistance for area consultants to assist the local district. Other programs provided instruction in order to prepare an experienced teacher to assume the responsibilities of a science supervisor. The emphasis in these programs was almost entirely on the cognitive development of the participant.

These programs established a very desirable relationship between the college and the cooperating partner to the benefit of teachers, particularly teachers of science and mathematics. Leadership in curriculum matters reached a peak probably never before realized in academia anywhere in the world.

The Problem

Having very briefly explored the development of the position of science supervisor, the primary question continues to remain unanswered. "If science is as important in the elementary and secondary school curriculum as science educators argue that it is, why is there an apparent lack of academic leadership in professionally preparing science supervisors?" Furthermore, "Why do so few school districts employ science supervisors, yet appear to have other supervisor specialists on their staffs?" Where there are science supervisors, their role is varied.

Science Supervisor Responsibilities in the Real World

Science supervisors in large school districts fill a variety of positions with accompanying responsibilities. At the secondary school level the science supervisor may be an extension of the position of science department chairman; or the position may be established to supplement that of the general curriculum supervisor, primarily because of the unique requirements of the science discipline. At the elementary school level the position of science supervisor, in most instances, does not pre-date 1955. These positions were established as nationally developed curriculum programs began to emerge. Science supervisors at the elementary level appear to be either (a) a former secondary school teacher of science who had an extensive academic and experiential background, or (b) a former elementary school teacher acclaimed by the administrative personnel in the district for his/her success as a classroom teacher and having a special interest in science. In no case was the science supervisor prepared through a pre-planned college program of studies.

How did the science supervisor become a part of the total state and local program? The answer seems to be "We do not know." Supervisors are functioning at all levels and are making unique contributions which will be described later in this chapter. Unfortunately their number is small, and there appears to be a need for additional science supervisors at all levels.

The science supervisor at the local school level seems to occupy a variety of positions in the school hierarchy. In some districts the supervisor holds a full time position and is responsible for the K-12 instructional program with all of its auxiliary requirements; in others the position is part-time, coupled with teaching responsibilities usually at the secondary school level; and in others two staff members share the responsibility, one at the secondary level and one at the elementary level. Fulfilling the position of science supervisor seems to have resulted from local needs and historical practices, both encompassing a variety of responsibilities.

Furthermore, there is a large variation in the locating of the position in the hierarchy or table of organization of a school district.

As far as can be determined, at the local level, the responsibilities of the science supervisor appear to be primarily administrative. Budget development, program implementation, curriculum selection and development, scheduling inservice programs, and staff recruitment seem to include most of the responsibilities of those serving in the position. In reality, questions have been raised as to whether these duties are truly "supervisory" or little more than "storekeeping activities."

Present Science Supervisor Training

A second question readily follows relative to the nature of the planned programs available in colleges and universities for those who aspire to the position of science supervisor.

It is interesting to recall that, during the years when the National Science Foundation was supporting science education, there were programs specifically designed for those preparing to gain a supervisor's position. Such programs usually included seminars in background information on various curricula, but the predominating academic requirement of the program was in subject matter courses. The major emphasis was again the cognitive. Very little experience seems to have been provided in fulfilling the supervisory role. Since NSF support has been withdrawn even this meager beginning has been reduced by the universities. Nothing has yet filled the educational void for teachers of science.

As a result of a search of the literature, a review of many college and university catalogs, and discussions with science educators in local, state and federal agencies, we find that most collegiate programs planned specifically for the future science supervisor require a minimal number of courses--perhaps one or two outside of those in the subject matter area. We find there are no programs through which a student could earn a professional certificate as a science supervisor. But where would such a certified person find employment? There seems to be a paucity of jobs for such people.

This situation appears to raise very serious questions relative to the influence and leadership activities of the professional organizations in science education. Have we not convinced school administrators and school boards of the fundamental importance of science in the school program? Is there not a particular need to have a professionally prepared staff member to work in a science supervisor capacity with teachers?

The Need for Science Supervisors

Many teachers, primarily elementary, attest to the need for a science supervisor who can assist them in the teaching of science. This recognized need results from a lack of subject matter preparation in a given college teacher preparation curriculum. Freedom of curriculum choice is the prevailing vogue at the collegiate level. Preservice elementary teachers usually satisfy the science requirement with introductory courses in the biological and/or earth sciences, with many of these courses being non-laboratory in design. As a result, science activities requiring a knowledge of the physical sciences cause the teacher to (1) panic and not teach science, or (2) seek a resource person who can explain the concepts and experimental procedures. The adequately educated science supervisor is the person who should be the resource to whom the teacher can turn for help. As long as colleges and universities persist in allowing the preservice elementary teacher to complete his/her degree requirements without completing at least one specifically designed, laboratory-oriented course in chemistry, physics, earth science and the biological sciences, there will be definite need in school districts for the science supervisor whose major responsibility is the cognitive area of teacher education.

In preparing secondary school teachers, we find that the usual college program continues to place much emphasis on subject matter knowledge. Very little instruction or experience is provided in the affective domain. It cannot be expected that changes in attitudes can result from additional education solely in the cognitive area. McIlwaine and Sleeman (9) reported that there was no significant change in attitudes on the part of 541 secondary school students who participated in programs designed to increase subject matter knowledge. Programs for preservice teachers must contain components in the affective as well as the cognitive areas. Preservice programs appear to be little affected by the newer methods and materials developed for use in the secondary school science programs. Consequently, in many secondary school science programs one finds little in the way of innovation. A science supervisor could provide the initiative to change these prevailing conditions.

A survey of instructors in science methods courses--both elementary and secondary--reveals the use of a variety of topics and approaches in the course outlines. In many instances an instructor will focus on a few topics to the exclusion of others which are equally important to the teaching profession. Again a serious omission results in the academic preparation of the preservice teacher. A competent science supervisor could provide consultant assistance to assist the inexperienced teacher to gain a level of competence necessary for effective classroom work.

A Stanford University (10) study of open area programs in the elementary schools found that a significant percentage of U. S. School administrators rated the preparation of teachers for open area teaching responsibilities as woefully inadequate.

This same attitude was expressed by school principals of metropolitan Vancouver, British Columbia, in a local survey (12). The data revealed that these administrators were virtually unanimous in expressing dissatisfaction with the preparation of beginning teachers for open area situations.

The variety of problems resulting from the diversity of approaches to teacher education should present conclusive evidence as to the need for a science supervisor at the local district level. If some local districts are considered too small for such a staff member, it is highly recommended that science supervisors be available through an intermediate educational agency or county office.

Ideal Science Supervisor Responsibilities

In 1967, the National Science Teachers Association published *A Sourcebook for Science Supervisors* (6), in which a broad overview of the role of the science supervisor was described. Most of the functions of the science supervisor described by Brewer et al. (2:11) in that publication are still considered to be valid responsibilities. In fact, questions have been raised by science educators as to whether supervisors have been able to fulfill the roles described because of the extensive demands placed upon them and limitations resulting from their particular position in a school hierarchy.

In summary form, Brewer et al. (2:11-16) list the tasks of the science supervisor under the heading of responsibilities as follows:

Responsibilities

General
Advisory
Professional growth
Improving instruction
Use of school and community resources
Equipment
Supplies
Facilities
Communication

Fulfilling these broadly stated responsibilities by the science supervisor requires that the supervisor possess three fundamental and all-encompassing qualities which we consider to be equally important. These include a broad resource of knowledge, an ability to communicate effectively, and a keen sensitivity to interpersonal relationships. These qualities can be and must be developed through effective academic programs which will lead to a science supervisor's certificate as well as a doctorate.

We recognize that the primary functions and major responsibilities of a science supervisor will vary with the particular position, i.e. the state level science supervisor, or the local district supervisor. However, the general responsibilities listed by Brewer do appear to be appropriate for any level of science supervision.

Snyder (13) states that when functioning effectively, the supervisor serves as a guide, a resource person, a catalyst, and an innovator to develop programs of education. A broad knowledge base, awareness of personal relationships, and the ability to communicate clearly will enable the supervisor to function effectively in the foregoing capacities.

Goldhammer (7) views supervision today as requiring a clinical relationship which promotes the teacher's capacity for renewal and eventually self supervision. This is markedly different from the older perspective of supervision in which the teacher was considered to be in a definite subordinate role. The sensitivity to interpersonal relationships was indicated by Parsons (11) when he wrote that supervisors must behave in ways congruent with the teachers' expectations for involvement, social support, and leadership.

Goldstein (8) develops a model for supervision which is also strongly oriented toward personal relationships. He writes that supervision (1) involves the experienced teacher in determining his own professional destiny, (2) provides a focus and precision in the performance of an experienced teacher, (3) eliminates the apparent mystique which seems to pervade the entire subjective evaluation process and (4) forces self-evaluation on substantive issues.

The knowledge resource and ability to communicate are summarized in the triad proposed by Doyle (3) in his model of the supervisor. He states that the functions of the supervisor are systematic observations, analysis of the teaching performance, and feedback of information.

Teachers have well-defined thoughts regarding the functions of a supervisor. The expectations of teachers regarding the science supervisor have been delineated by both Bongarzone (1:20-22) and Woodburn (15:23-26) in the aforementioned Sourcebook. The former writes that a science teacher expects the supervisor to conduct constructive observations, provide an insight into the operation of the school district, be a source of information on curriculum innovation, and assist the teacher in planning for self improvement. Woodburn's findings reveal that the supervisor can increase classroom effectiveness through effective communication, can be of assistance in solving problems which arise in the classroom, can improve the effectiveness of the teacher through meaningful evaluations, and can assist the teacher in the very broad concerns of reaching the educational goals of the district.

In view of these perceptions of the supervisor, it would appear that the function of a science supervisor should be a conscious and deliberate effort in shaping what one might consider the major elements available to the teacher in order to attain the objectives of instruction. The composite of these elements is the curriculum, which includes the variables time, space, teaching (with a variety of methodology and materials) and learning (with the emphasis placed on the individual learner), and the personal involvement and relationships between and among administrators, teachers and students, all circumscribed by that block of time we commonly call a schedule.

In the broadest possible sense the primary concern of the science supervisor must be with the curriculum. In demonstrating this concern many forms must be exemplified and demonstrated.

Innovation and the Supervisor

The recent research of Hall reveals areas previously not described in which the science supervisor must function. Hall and Rutherford (5) report that teachers can be classified into different stages when involved in curriculum innovation. These stages are identified and briefly defined as follows:

Unawareness:	unconcerned about the innovation.
Informational:	concerned about general characteristics of the innovation and the requirements for use.
Personal:	concerned about the teacher's role and possible conflicts between that role and anticipated demands of innovation.
Management:	concerned about time, organization, managing classroom and making the innovation work smoothly.
Consequent:	concerned about student outcomes.
Collaboration:	concerned about working with others in the use of the innovation.
Refocusing:	concerned about finding another and even more effective way.

Certainly one of the functions of a science supervisor would be to identify the stages in which teachers in his charge are classified, then through skilled supervision and assistance help guide them to move from the less to the more desirable stages.

Science educators might conjecture that had more school districts employed science supervisors who were skilled at using a classification form similar to the above, a higher level of success would have been realized in those school districts which adopted student-oriented science programs.

Although the authors have not refined the procedures and the data which they collected in working with many curriculum innovations to the extent done by Hall and Rutherford, they also found that teachers could be stratified into various stages which revealed their concerns, or attitudes, toward new science curriculum programs. Referring to the stages proposed by Hall and Rutherford, the authors were able to classify teachers into the stages of Unawareness, Management and Refocusing.

Another function of the science supervisor is to determine how long he/she must provide a support mechanism for the classroom teacher. It had been assumed much too long, and much too unrealistically, that teachers did not need assistance when attempting curriculum innovation. This was probably predicated in part, at least, on the belief that the teacher is a professional and is capable of adopting innovations without auxiliary assistance. Science educators know that innovative programs made possible through the support of the National Science Foundation, in which a consultant worked with the teacher on a regular basis in the teacher's classroom were very successful when compared with innovations which were attempted without the assistance of a competent supervisor-consultant. The findings of the professor-consultants who cooperated in the research on curriculum installation conducted by the Eastern Regional Institute of Education (ERIE) confirmed the recognized need for classroom teacher assistance.

The ERIE program* was a clinical model of supervision in which the professor-consultant helped the teacher involved in a curriculum installation to recognize necessary and desirable teacher changes in classroom practices. Cooperatively they planned and worked toward those changes. Initially the teachers sought reassurance (Typical question: "Am I doing all right?"); they then sought subject matter information ("In the manual it is stated that __________. What is the explanation for that reaction?" or "Why did this cylinder reach the bottom first?"); finally, after having satisfied their own needs they began to recognize, assess, and deal positively with the students needs ("What additional activities can I provide for the student?"). Thus, they allowed, and even encouraged, the students to progress through the learning processes which they, themselves, had experienced.

Research in curriculum installation has suffered a very serious setback as a result of the short-sighted decision of the Congress when it prohibited the National Science Foundation from supporting curriculum installation programs in science, social and natural, and mathematics education. Hopefully, the members of AETS will take an active role in convincing the members of the Congress to reverse their decision which is so unfavorable to the teaching profession.

How long must supervisor-consultant assistance be provided to the teachers in a school or district while they are implementing an innovation or curriculum program? The experiences of the authors, plus the other professor-consultants in the three years of the ERIE program study and four subsequent years of their own consultant implementation studies reveal that innovative programs cannot be implemented successfully in a single year but require at least two, and as many as four years, to reach a success level. Two years seems to be a minimum just to enable the teacher to feel confident teaching the program. Changing teacher needs and concerns appears to be the primary influence in determining the length of time needed for successful implementation.

Hall and Rutherford (5) also found that implementing an innovation cannot be accomplished in a very short period of time, usually a year or less. In the innovation studied (Teaming), Hall and Rutherford found that at least three full years are required to fully implement this innovative method of teaching.

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*Information provided was based on personal experience. Direct inquiries to William B. McIlwaine.

The results of Hall's research clearly identifies another function of the science supervisor not previously described in the literature. The supervisor must monitor curriculum innovations adopted by a school district and provide progress reports on the installation of the innovation. Only after the data indicate a successful implementation can the attention of the supervisor be redirected and focused on other functions.

The results of additonal research conducted by Hall et. al. (4) provide a valuable referent available to the supervisor to enable him/her to reach decisions relative to the level of use of any innovation. This, indeed, should serve as a valuable tool to the supervisor in determining the actions that should be taken to insure successful implementation of the innovation. Hall, et. al. (4) have developed a Levels of Use (LoU) Chart which describes the various behaviors demonstrated by teachers as they move through different stages in adopting an innovation. Hall states that "The LoU dimension is an attempt to define operationally various states of innovation user behavior. The reason the innovation user does certain things is a reasonable question only after how the user behaves can be systematically described and measured." Successful use of the LoU dimension will fulfill the necessary prerequisite for the science supervisor to focus on attitudinal, motivational and other affective dimensions, which are, indeed, fundamental concerns for successful supervision.

Needed Research

Do the perceived personal needs of teachers change from one year to the next? Are their needs different during the second year after the experiences of the first year? What happens after the teacher receives tenure? Do the functions of the science supervisor change with the years of teaching experience of the clients? Or, are all of the same functions required with a change, slight or otherwise, on the emphasis required? Does the science supervisor perceive that the needs of teachers change with years of service?

There is sparse evidence in the literature that these kinds of questions have been researched by the science educator. Perhaps they are not important? Perhaps there is no variation of perceived needs in relation to years of service? This does not seem to be a realistic assumption, however.

It must be emphasized that the role of the science supervisor must be fulfilled with the prevailing administrative structure in the school district if the person is to be successful in completing the tasks of the position. This is not to concede that the supervisor should be meekly submissive to administrative fiat. It does mean that, as well as educating classroom teachers, the science supervisor may have to strive to educate the administrators with whom he/she works in order to develop the position to its most effective potential. It should be an interesting study to investigate the perceived effectiveness of state level and school district level science supervisors as related to their position in an administrative structure so that meaningful data would be available to the profession.

In Conclusion

If a science supervisor needed all of the expertise judged necessary for successful fulfillment of the perceived functions there would be very few, if any, who could humanly meet the requirements!!! If a science supervisor could function in all of the roles that are described, and implied, by those who write, there would not be enough hours in any day to successfully complete all of the tasks. What then, in summary, are some realistic expectations of the science supervisor?

Teachers have selected the profession for their life's work by choice. They look to the science supervisor to help them to be successful in this commitment so that the greater benefit will accrue to the students in their charge. In helping the teacher, through direct and indirect intervention, the primary emphasis must be in assuring success in both long term and short term tasks. Curriculum change and/or innovation is an example of the former, while ordering correct items for science experiments is an example of the latter.

A science supevisor should:

1. have a commitment to teaching so that he/she is able to teach at any given level or subject and effectively model a variety of teaching methods.
2. be able to communicate effectively with the school administrator and classroom teacher in order to effect successful change or innovation. Communication includes listening attentively and with interest as well as being able to say what should be said without relying on meaningless words and phrases such as "I" and "you know."
3. be competent in observing lessons and provide meaningful critiques and feedback in order to assist the teacher in achieving personal and school-district goals. This clinical supervision should help the teacher to develop self-supervision capabilities.
4. determine the stage of implementation at which an innovation or curriculum change may be and work closely with the administrators and classroom teachers to insure effective implementation as quickly as possible. This function will help the teacher to identify problems of management and organization from content or program among others.
5. demonstrate a knowledge of learning theory and curriculum principles so that adaptation of programs can be completed successfully.
6. know how to evaluate the academic needs of teachers in order to plan meaningful programs of inservice instruction. In a similar way, the supervisor must be able to conduct "needs assessments."

7. through active membership in appropriate professional organizations, be able to provide resource material for curriculum, physical plant and personal needs.

8. strive to help teachers and administrators to develop content-integrated learning opportunities for students to the end that programs of human concerns will supplement the content concern which now prevails in too many of our schools.

9. seek and establish a professional relationship with college and university science educators so that the resources of higher education will be available for mutual benefit and together they can demonstrate a leadership in identifying new dimensions in science education.

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CHAPTER 5

DOCTORAL PROGRAMS FOR SCIENCE EDUCATORS

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In his unforgettable manner, Charles Dickens' analysis of the development of Scrooge through Christmas Past, Christmas Present and Christmas Future has enabled us to have a vicarious experience of the growth of an individual. In a similar manner, it is also possible for us to reflect on the growth of a relatively new emerging and hopefully maturing professional group--the professional Science Educators.

THE DOCTORATE IN SCIENCE EDUCATION
PAST: THE 1960'S

The professional science educator was an emerging figure in American Education in the early 1960's. In speaking of education in general, Richardson and Howe (3:1) stated: "Our knowledge of professional education is partial--in both its theoretical and applied aspects." Such was also true in the opinions as to what should constitute the graduate program of a science educator. Many kinds of ingredients were found to characterize the more than 25 doctoral programs in existence in the early 1960's. But the rationale of these programs seemed close to the non-rationale of general education programs in the sciences--as described by Richardson and Howe:

> Even with all our confidence in the appropriate role of content in the education of the individual, we seem to be working principally on the basis of hope and faith that the employment of the traditional systems of knowledge in the various fields of science are adequate to the most adequate development and exploration of the intellect (3:1).

Faith and hope still characterized the call for specific description of the preparation of the doctorate in Science Education in 1974 (1). While this study of characteristics of the doctorate was a documentation of what the researcher should know who was engaged in

> . . . exemplary research and research-related activities in education. This . . . study was initiated to begin filling a void of existing knowledge of training of educational research and research-related personnel, namely the lack of information on the specific tasks performed by such personnel and the specific competencies required of them in performing these tasks (1:2).

While the listing of such competencies did not exist in most subject areas, in the mid 1960's the collective wisdom of active science educators as reflected in the Guidelines for the Doctorate in Science Education (2) was adopted as a working paper. This publication was sponsored by the Association for the Education of Teachers in Science. It was developed by a committee of seven during 1964-66 and adopted by the entire membership after extensive discussion and modification on April 1, 1966. This discussion of the doctorate past is thus based on that report as it reflected the views of the majority of the science education community. At that time it was recognized that there were variations in doctoral programs in science education as they existed at different universities. It was believed that this variety should continue to exist but not without some common elements. Within the doctorate in science education it was agreed that a member of our profession should have had the opportunity to be immersed in on-going research, curricular development, and supervised clinical experience. That a professional science educator could be the product of a program in which research, curriculum development and clinical practice were absent was a deep concern to some science educators in the 1960's. In fact the impetus or moving force behind a development of the Guidelines was a felt need for standards that would help improve doctoral programs. In this hoped-for-improvement, two weaknesses were identified: inadequate preparation in one's science teaching field and inconsistent admission standards.

As new programs were rapidly emerging in the 1960's, the Guidelines were generated to help shape these programs. It was clearly specified that a doctorate in science education should not be an alternative route for the graduate student who couldn't quite make it in doctoral study in a science area. As a group, science educators were saying that Science Education represented a definable field of scholarly endeavor which had earned the right and obligation of respect as a professional entity.

In the mid 1960's science educators were viewed as persons who provided leadership in science instruction for kindergarten through the twelfth grade; leadership in preservice teacher education; leadership in school supervision of science instruction including inservice teacher education; and leadership for research in science education. At that point of time the teaching of science at the college level was intentionally omitted as a legitimate role expectation for a science educator.

Requirements for admission to a doctoral program in Science Education were expected to be the same as those requirements for admission to other doctoral programs at an institution with some added requirements. To effectively demonstrate a level of competence in one's science teaching field, mathematics through calculus was identified as a prerequisite. To insure that members of the profession would have an adequate time to productively contribute to the profession, admission of individuals older than 35 was strongly discouraged. To enable graduate study to build on the reality of the profession, i.e., teaching, a minimum of two to four years of teaching experience was identified as an essential prerequisite.

Reflecting the expected role of a science educator as an essential link between the academic community of science departments and the reality of the K - 12 classroom, the *Guidelines* for the doctoral programs specified that each graduate should have functional skills in seven areas.

1. Science,

Depth in Science. By the time of completion of the doctoral program in science education, candidates should have the equivalent of a contemporary master's degree in an area of science. This means that if they earned a master's degree in an area of science some years earlier, they should, during the period of their doctoral studies, take enough additional graduate courses to bring themselves up to date (4:33).

Breadth in Science. The program should ensure that the candidate has at least a one-year course with laboratory in each of the usual school sciences, namely, biology, chemistry, physics, and earth science. While this requirement may in many cases be fulfilled prior to admission to the doctoral program, courses or other means should be used to ensure that the candidate is knowledgeable about modern content and emphasis in these basic areas (4:33).

2. History and Philosophy of Science,

While ideally a full-year course in each of these two subjects might be desired, there are many practical difficulties in fitting them into a program. However, the candidate should be expected to complete no less than a year's study in one or the other of these subjects, a year of study divided between them, or a year's course encompassing both (4:33).

3. Science Education,

By whatever means, the candidate should become well informed about past advances in science education and reach the forefront of curricular and other developments in this field. An advanced course or substantial seminar should be the minimum, but a large number of courses in science education should not be required (4:34).

4. Psychological, Sociological, and Philosophical Foundations,

An advanced course or seminar based on each of these disciplines should be expected. The candidate should have an up-to-date knowledge of role orientation, group dynamics, child development, cognitive and personality psychology, and of the school as a social institution (4:34).

5. Statistics,

No less than one full year of study which would carry the student through experimental design and covariant analysis or the equivalent should be required. A knowledge of some computer techniques would be desirable (4:34).

6. Mathematics,

Candidates should take one year of college mathematics in addition to the year required for admission. This should be calculus unless the candidate has already taken it (4:34).

7. Research Involvement,

During the period of residency, candidates should be actively engaged in experiences pointing directly toward career goals. For example, with counsel and criticism of their performance by staff members in science education, they might teach portions of a methods course or participate in supervision of science teachers.

During residency, candidates should be involved in some aspect of research in science education. This is to be expected especially of those candidates who are not going to be primarily research workers. In order to meet this standard the institution must have adequate research facilities and suitably staffed on-going research activities, including research in science education.

A dissertation should be required so candidates can demonstrate their capability to plan and carry out a significant independent study. While the study should be restricted in scope so that the candidate can complete the dissertation in a reasonable time, it should nevertheless be significant enough and of such quality that it can serve as the basis for a report to the profession. The report will ordinarily take the form of a paper delivered at a conference, a published article, or preferably both.

The doctoral committee which supervises the work of a candidate in science education should contain representatives from relevant academic areas (science disciplines, psychology, statistics, etc.) and from education. History and/or philosophy of science are accepted as appropriate disciplines.

The program should require at least two years, preferably consecutive, or full-time residency. In some cases one year of residency obtained during a recently completed master's degree program may be included, but in no case should a candidate be permitted to obtain the doctor's degree without spending one academic year in full-time residence on campus (4:34).

The Doctorate in Science Education-Past has depicted an emerging professional person whose varied roles required respectability in the scientific community and at the same time (and equally important) creditability in the teaching profession. Science education itself was viewed as a profession with a doctoral level of scholarly study and research with which its members could identify.

THE DOCTORATE IN SCIENCE EDUCATION
PRESENT: THE 1970'S

In 1972 the then President of the Association for the Education of Teachers in Science, Paul Westmeyer (and a member of the original Guidelines committee), established a Commission on Revision of the Guidelines for the Doctorate in Science Education. This commission consisted of eight members with six Regional Advisory Committees, each reporting to a member of the commission. Members of the Regional Advisory Committees reviewed the 1966 Guidelines and suggested needed changes. These changes were formulated into a draft of Revised Guidelines which was circulated to all members of the commission and to the Regional Advisory Committees. The final report of the Commission was drafted, based on the feedback from both the members of these groups and from general meetings of the membership of the Association for the Education of Teachers in Science at its national meetings of 1974 and 1975. The product of this effort was Guidelines for the Doctorate in Science Education (2). This discussion of the doctorate present will be based on these Guidelines and the point that science educators in general recognized that ten short years after the 1960's and after a single decade of impressive growth, science educators have experienced an observable shift in expectation and in the relative emphases in their preparation programs. In part this shift is reflected in the emergence of the belief that the goals of a doctoral program should reflect the societal context in which the products must exist. Thus members of the science education profession are being called on to deal with alternatives rather than with solutions--first words for current concerns rather than last words for old problems. In contrast to "faith" in curricula (and other software) as ways to answer the question about what is the most accurate science knowledge that should be part of schooling, science educators today are confronted with issues such as "the quality of life," "accountability," "individual worth," and "integrity." A single curriculum package for all concerns is obviously not adequate. Many science educators find themselves functioning as change agents rather than as installers of pre-packaged curricula.

A second definite shift in emphasis in today's science education programs is the focus of helping science educators deal with other people. This humanistic emphasis in doctoral programs illustrates how the demands of the 1970 societal concerns are mirrored in the expectation of members of professional science education groups.

> A science educator must make decisions about what, how, and when learning is needed. Thus, graduate study should reflect these concerns through work done in a setting that emphasizes ongoing real problem seeking and solving. Such a setting could be a classroom, a functioning teacher center, a curriculum development/research effort, or other related contexts (2:30) (Emphasis added).

The specific areas of competency expected of today's science educators are selected to enable them to be flexible, creative, reflective and sensitive in their work with a variety of people. Within this work, a science educator is expected to be one who can work with a variety of people and with the problems that they see as significant.

Admission to today's doctoral program is keyed to flexible criteria to enable programs to meet the existing supply and demand for science educators. Admission criteria are expected to be essentially the same as for entrance to comparable graduate programs at an institution, with few specific additional considerations.

- Does the prospective student have a definable breadth and depth in a science teaching field?
- Does the prospective student have an adequate base of classroom experience relevant to area of proposed study?
- Does the prospective student have potential for leadership in science education?
- Does the prospective student have both interest and potential ability to identify and study problems in science education?
- Does the prospective student have future goals for which the program of doctoral study is appropriate?

These questions are closely related to the expectations of performance of science educators which were specified in the 1974 Guidelines.

> Personal characteristics that will contribute to the science educator's professional competencies include flexibility, creativity, reflectivity, and sensitivity:
>
> Flexibility in order to:
> Work with an expanding base of educational systems, from free school to graduate college, from general education to career and continuing professional education; communicate with people who possess characteristics and value systems different from their own; continue to contribute leadership in areas of personal competence as society and education change over time.

Creativity in order to:

Develop, *implement*, and *assess* preservice and inservice teacher education programs consistent with research evidence and the expected outcomes of science teacher education; design and evaluate science curriculum materials appropriate for selected audiences and learning outcomes. *Select*, *demonstrate*, and *assess* instructional strategies and styles which are consistent with the openness of science, the learning/cultural environment, the learner, and the teacher.

Reflectivity in order to:

Identify societal needs significant to science instruction and learning. *Judge* the relative merits of alternative learning environments for science teaching, including the assessment of science materials, the characteristics of the science teacher and the suitability of the overall instructional impact on the learner.

Sensitivity in order to:

Aid others to assess and modify their own teaching behavior; *assess* and *modify* personal values and behavior in terms of individual competencies and self-concept and the way they are perceived by others. Thus, a science educator must possess a knowledge base in science and in education, and must be able to work with people and the problems *they* perceive as relevant. The science educator must be a constructive and creative user of information utilizing a variety of facilitating personal characteristics (2:30).

The emphasis on being able to work with other people was translated into eight competency targets for the doctoral program.

1. Competence in Science

Individuals who expect to deal with the wide range of science learning environments within the education system should have considerable breadth of learning in the science. The option for study in either breadth or depth in science should be open. Either the equivalent of a master's degree in a science area or an undergraduate major in one area plus breadth of work in several other areas are possibilities. The totality of the work should permit creative thinking about the interconnectiveness between the several subbranches of science, the interdependence of science and society, and the processes and styles of scientific pursuit that distinguish it from other intellectual endeavors, as well as the procedures and styles which link science to other intellectual pursuits (2:30).

2. Competence in the Social Context of Education

Competence in this area requires an understanding of school organization, structure, and sociology. The science educator needs an understanding of the socioeconomic and political forces which have shaped education in general and science education, particularly in the past, and which continue to influence both the systems we now have and the teachers and students that are part of these systems. Of particular importance is the need to understand the processes by which change occurs and how individuals learn to cope with the changes or participate in the processes (2:30).

3. Competence in Design or Development of Curriculum

The development of curriculum materials, implementation models, and teacher preparation schemes depends upon the application of principles from associated fields such as sociology, anthropology, psychology, and communication research. The science educator's knowledge is essential in these areas to the extent that these areas contribute to science curriculum decisions. It is crucial that science educators have knowledge of the various models for development and learning, their psychological bases, and the translations of these models to instructional practices. They should be able to supply analytical procedures from sociology and anthropology to educational systems as related to value and attitude formation and apply the technology of communication research in science teaching where the transmission of information is a goal. They should use this knowledge in the identification of science education goals and readiness for learning that are peculiar to cultural subsets of our society (2:31).

4. Competence in the Instructional Process

The function of a science educator requires skill in analyzing and evaluating plans for curriculum designs, instructional materials, and teaching strategies. Such skill includes knowledge of materials and technology available and alternative tested instructional techniques. It also includes the ability to adapt materials and strategies to new situations, to recognize effective innovations, and to suggest appropriate alternatives (2:31).

5. Competence in Instructional Evaluation

Skill in instructional evaluation is twofold. The first skill is to be able to interpret results objectively in relationship to the context from which they were obtained. Second is the ability to communicate with prospective and experienced teachers in such a way as to stimulate an examination of their own teaching processes (2:31).

6. Competence in Research Design

Competence in this area includes skill in recognizing important questions, giving these questions an operational form by considering alternative methods and forms of design, formulating testable hypotheses, applying controls when necessary, and utilizing procedures for analysis of data. Related skills are the ability to communicate results effectively to a variety of constituent groups and the ability to read and interpret the research of others (2:31).

7. Competence in Administration

Two skills are relevant in functioning within universities and colleges as institutions and their related agencies. First is the ability to communicate the design of a study or project in such a way as successfully to secure support from appropriate sources. Second is the skill of administering funds once they have been secured (2:31).

8. Competence in Interpersonal Skills

Competence in this area includes the enhancement of a self-concept and the formation of a set of values that can serve as a reference point for reflective thinking and change. This need includes knowing how others perceive one in a variety of roles as an educational leader, skill in listening to what people say, and the ability to interpret and act upon this input in sensitive and constructive ways (2:31).

CONTRAST IN THE PAST AND PRESENT OF THE DOCTORAL PROGRAMS IN SCIENCE EDUCATION

Looking back at the description of the Doctoral Programs in Science Education - Past and Present as reflected in the 1966 and 1974 Guidelines, clear contrasts are observable.

First, the purpose for the Guidelines documents themselves shifted from a set of guides for developing a program to a set of guides for analysis of already developed programs. Most science education doctoral programs are now functioning. A very limited number of new programs are expected to emerge.

Second, the expectations of a doctorate in Science Education have been expanded from leadership roles in college teacher preparation, school supervisors and research to flexibility, creativity, reflectiveness and sensitivity in performance in these three areas plus instructional problems in the teaching of science at the college level.

Third, admission critera are concerned less with specific age, prerequisite mathematics and teaching experience and more with the potential ability and interest of the prospective student to function as a contributor to the profession.

Fourth, there is a discernable shift in the program recommendations from skills and understandings of science as it is and as it is found in schools to skills involving people working with people with problems they find relevant--or in science as it affects people. Thus in these areas the specific recommendations have changed in program requirements.

		1966	1974
1.	Science	- Depth and Breadth expected	More flexible
2.	Social Context	- About one year's work expected	Very similar
3.	Science Education	- Limited analyses of past trends	Expanded to three areas of competence - instructional design - instructional process - instructional evaluation
4.	Research Design	- Statistics tools and dissertation	The integration of statistical tools to science education research
5.	Grant Administration	- Not included	An added emphasis
6.	Interpersonal Skills	- Not included	An added emphasis

THE DOCTORATE IN SCIENCE EDUCATION -- FUTURE

An analyses of past and present goals of doctoral programs in science education can be considered an exercise in futuring. They can be the basis for predicting how we think the doctorate should look, provided we can assume that future needs and opportunities will be similar to those of the past. That assumption must be questioned, however. A second significant question remains to be answered if we are to have an adequate base for describing the future. How accurately do the goals describe the programs of doctoral study in science education as they actually occur in the 1970's?

To answer this question, in August of 1975 twenty-two doctoral programs were selected for study. These 22 programs were selected as being locations of known active sources of doctorates--and included most of the institutes surveyed in the 1964 study (3:87). Key faculty at each of these institutes responded to these questions via a telephone interview.

1. What are the characteristics of incoming graduate students?
2. What is the match between the 1974 Guidelines and current program admission practices?

3. What is the match between the 1974 Guidelines and the current program requirements?

4. How many applicants are currently being accepted and what is their completion probability?

5. What is the current utilization of graduating doctorates and what are the expected changes in admission to programs and output utilization?

What are the Characteristics of Incoming Graduate Students and the Match Between the Guidelines and Current Admission Practices?

Currently, there is a range of expectancies of the incoming student. As illustrated in Table 1, at most institutions more students apply than are admitted. However as seen in Figure 1 there is a range in the ratios of acceptance to applications from less than 25 percent to 100 percent acceptance. Most institutions accept about half of their applicants.

The list of reasons given for not accepting serious applicants represents a picture of how our current practice parallels the recommendations of the Guidelines (Table 3). It is interesting to note that while the emphasis on the science teaching field of the doctorate is supposedly receiving a somewhat lesser emphasis, it still represents the largest screening factor in the minds of most of our colleagues in science education. In many programs, (12 of 22) the applicants are only considered if they have completed a master's degree in their science teaching field prior to beginning their doctoral study. Admission to graduate study includes satisfactory Graduate Record Examination scores (or Miller Analogy scores) and satisfactory GPA. Previous teaching experience is required for 14 of 22 programs although at many of the institutions this experience may be acquired as part of the program of graduate study.

Today's beginning graduate student appears to be one, selected out of a much larger population, who has satisfactory scores in the GRE, adequate previous academic performance (GPA), appropriate teaching experience and a discernable identification with and commitment to science education as a profession. Even with these qualifications, it is equally interesting to note that the likelihood of an admitted student completing the doctoral study varies from 100 percent to 17 percent (see Table 1). In 14 of the 22 institutions surveyed the ratio of those completing the doctorate was 50 percent or less of those that started. Unanswered is a significant question--should our admission criteria enable us to screen out more of those who are unlikely to complete a doctorate before they commit themselves (and the institutional resources) to an incomplete task?

The present suggests that in the future we will be screening, and selecting for admission, students based on criteria that are not consistent with our own statements of professional concern.

Table 1

Applicants to Doctoral Programs in Science Education

Institution	Number of Applicants per year	Ratio of Acceptance To non-acceptancies	Ratio of Completion
1	15	2 of 3	60%
2	20	1 of 4	100%
3	10	1 of 2	50%
4	30	1 of 3	70%
5	40	1 of 20	100%
6	4	1 of 2	100%
7	8	1 of 2	25-50%
8	12	all accepted	40%
9	15	4 of 5	25%
10	25	1 of 2	75%
11	10	all accepted	50%
12	8	3 of 4	50%
13	60	1 of 2	40%
14	15	1 of 3	50%
15	35	1 of 2	17%
16	10	1 of 3	66%
17	12	1 of 3	50%
18	70	1 of 6	50%
19	15	1 of 4	75%
20	30	1 of 2	33%
21	20	3 of 4	33%
22	20	1 of 10	50%

Figure 1

Acceptance of Applicants
in Science Education
Doctoral Program

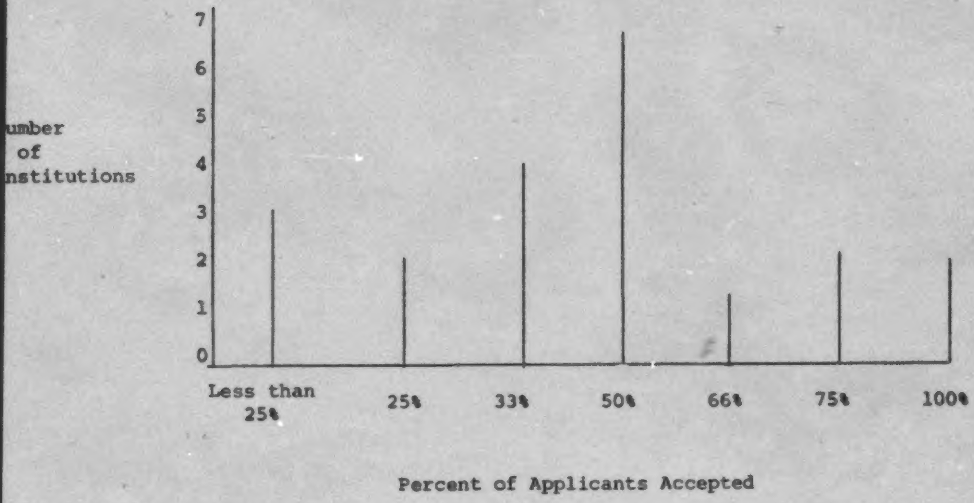


Table 2

Admission Requirements to Doctoral Programs in Science Education

Institution	GPA	GRE	Masters Degree in Science	Teaching Experience	Other
1	yes	yes	yes	1 year	Satisfactory performance in University battery of tests
2	yes	yes	yes	no	Satisfactory performance in test of writing ability
3	yes	no	yes	no	
4	yes	yes	yes	2 years	
5	yes	yes	yes	5 years	Self constructed statement of purpose
6	yes	yes	no	2 years	
7	yes	yes	yes plus 1yr. in 4 areas	1 year	
8	yes	yes	no	no	Personal interview required
9	yes	yes	no	3 years	Personal interview required
10	yes	yes	no	2 years	
11	yes	yes	no	no	Personal interview recommended
12	yes	no	yes	no	Personal interview required
13	no	no	yes	2 years	Personal interview & a seminar presentation required

Table 2 (continued)

Institution	GPA	GRE	Masters Degree in Science	Teaching Experience	Other
14	yes	yes	no	2 years	
15	yes	yes	yes	2 years	
16	yes	no	yes	Desired (not required)	
17	no	yes	no	no	Personal interview required
18	yes	yes	no	2 years	Must agree to two year residency
19	yes	yes	no	3 years	
20	yes	yes	no	2 years	
21	yes	yes	no	3 years	Strong letters of support. Personal interview recommended
22	yes	yes	yes	no	Personal interview

Table 3

Reasons Identified for Non-Acceptance in Doctoral Programs in Science Education

Frequency Cited	Reason
13	Lack of academic depth or breadth in science.
10	Lack of commitment to Science Education as a profession as indicated by non-interest in time of residency requirement or interest in only securing a Doctorate.
9	Lack of understanding what Science Education as a professional goal is.
9	Lack of teaching background or experience.
6	Inability to express themselves in writing or in personal interviews.
5	Lack of match between program and person's professional goals.
4	Lack of previous collegiate performance (GPA).
3	Inadequate or unsatisfactory previous employment record and recommendations.
1 each	Over age 40. Lack of understanding of science in a current mode. Rejected at other institutions. Lack of adequate leadership potential.

What is the Match Between the Guidelines and Current Program Requirements?

If indeed, the Revised Guidelines accurately reflect new or changed demands on science educators, then the future graduate of today's programs should be entering the profession with the competencies as described in the eight Guidelines. The match between these competencies and current program practice thus becomes an important question. In most graduate programs, it is possible for the competence to be acquired through a formal requirement, e.g., specific courses, or an informal part of the clinical experience of the graduate program, or intentionally omitted from the program.

The description of how each of the eight Guidelines is included (or excluded) is in Table 4. The specific strength of a doctoral program, as identified by the institution, is also noted. In figure 2 the frequency of formal or informal emphasis of each of the eight Guidelines suggests that in general our current programs reflect consistent emphasis on the first six Guidelines.

Only one program included any formal emphasis on Guideline 7 (Administration of Grants) and 13 of the 22 surveyed have no experience at all in this area. Five of the 22 programs surveyed have formal requirements with the 8th Guideline (Interpersonal Skills) while, even on an informal basis, 12 have little or no emphasis in this area. To this extent, the Guidelines describe two sets of skills for the professional science educator for which current programs and faculty are unwilling to consider as being of appropriate academic concern. At present if a science educator is to have these skills, they must be acquired in ways other than part of formal or informal graduate study.

Further study of Table 4 and Figure 3 illustrates the diversity of emphases in doctoral programs.

For prospective students interested in the social context of science education, six programs are perceived as being strong in the area. The development of curricula is a significant strength of 15 of the 22 programs which suggests that it would be more likely for a prospective graduate student to select such a doctoral program if this was an area of keen interest. If a student expected to be involved in working with people in supervisory capacities, as for example serving in an instructional role as contrasted to a judgemental role in supervision of student teachers, in only one program is this skill valued enough to be perceived as a significant strength.

The diversity in programs reflects the differing interests of the faculty involved. However, at this time a description of the programs at different universities for study by a student who is considering possible graduate study is not available to assist them in selecting a program to fit their interests. The importance of this lack is underscored where one of the key reasons for not accepting applicants for graduate study is the non-match between the prospective student's interest and specific program capabilities as illustrated in Table 2.

Table 4

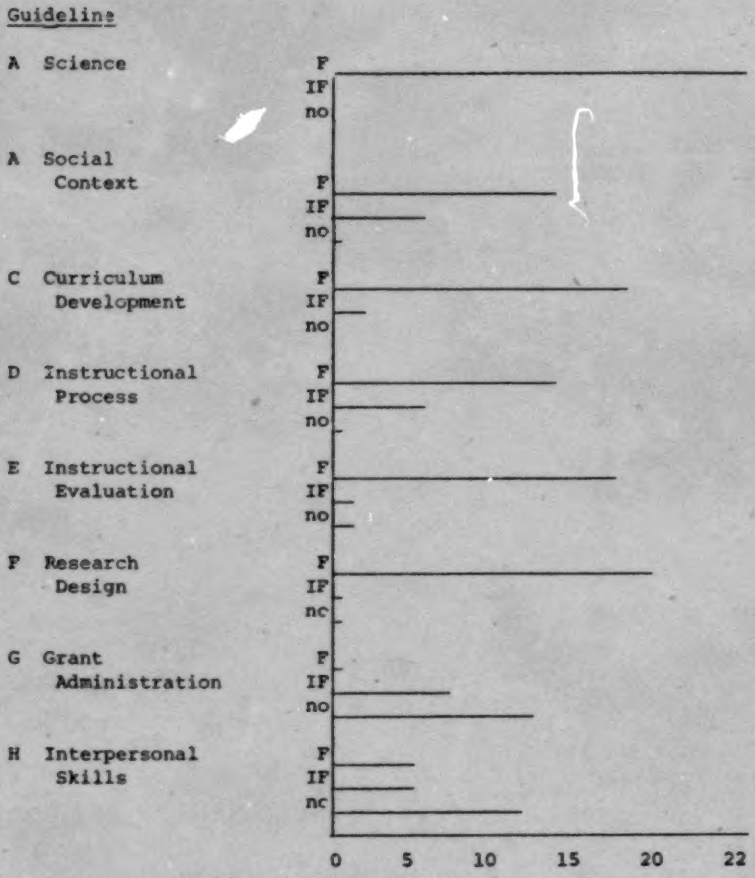
Current Doctoral Program Requirements

Institution	Guidelines							
	A	B	C	D	E	F	G	H
	Science	Social Context	Curr. Dev.	Inst. Process	Inst. Eval.	Research Design	Adm.	Interpersonal Skills
1	F	IF	F*	F*	F*	F	IF	F
2	F	IF	F	IF	F*	F	no	no
3	F	IF	IF	IF	F	F	no	no
4	F	F	F*	F*	F*	F*	IF	no
5	F	F	F*	IF	F	F	no	F
6	F	F	F	F*	F*	F	no	no
7	F	F	F*	F*	F*	F	no	no
8	F	F	F*	F	F	IF	F	F
9	F	F	F*	F*	IF	F*	IF	IF
10	F	no	F*	F*	F	no	IF	IF
11	F	F	F*	F*	F*	F*	no	F*
12	F	F	F*	IF	no	F*	no	no
13	F	F*	IF	IF	F	F	no	no
14	F	IF	F*	no	F*	F	no	no
15	F	F*	F	F*	no	F*	no	IF
16	F	F	F	IF	F	F	no	no
17	F	F	F*	F*	F	F	IF	F
18	F	F	F*	F*	F*	F	IF	no
19	F	IF	F*	F*	F*	F*	IF	IF
20	F	IF	F*	F*	IF	F*	no	no
21	F	F*	IF	F*	F*	F*	IF	IF
22	F	F	F*	F*	F*	F*	no	no

When F = Formal Requirement
IF = Informal Requirement
* = Special Emphasis Strength

Figure 2

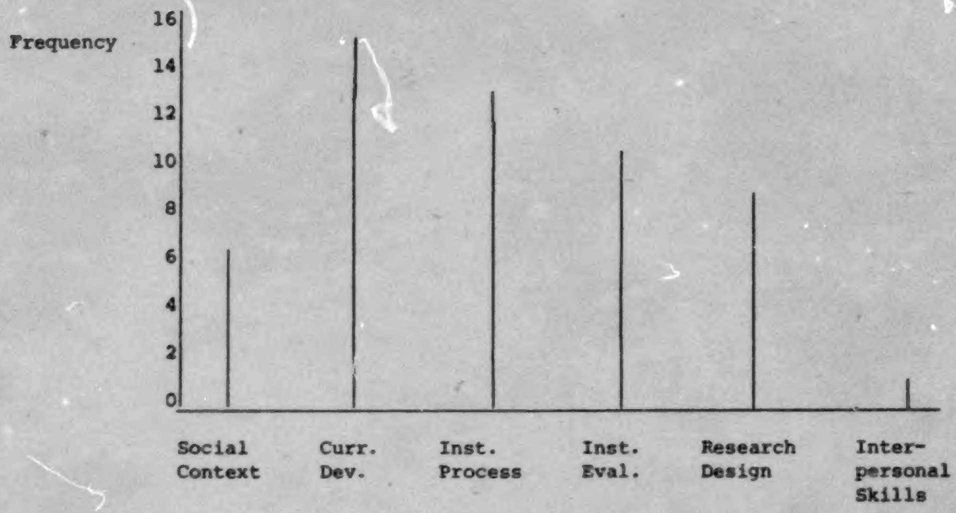
Frequency of Formal and Informal
Requirements of Guidelines in
Science Education Programs



F = Formal
IF = Informal Requirement
No = Omitted from program

Figure 3

Doctoral Program Strengths
as Identified by Institutions



The Past and Present strongly suggests that in the Future, our doctoral programs in science education will continue to reflect the strength and interest of the faculty. To the extent that these strengths and interests are shaped by programs of graduate study the exclusion of areas of needed study described in Guideline 2 (Social Context), 7 (Administrative) and 8 (Interpersonal Skills) will continue.

What is the Current Utilization of Doctoral Graduates, and How is This Reflected in Current and Projected Admissions?

An even more interesting glimpse for the future is found in Table 5. The current size and projected needs when compared to current and projected numbers of graduates depicts a grave imbalance. Most graduates will be entering the community of science educators with specific expectations for opportunities of university level positions. These positions clearly will not exist during the next five years.

As seen in Figure 4, other possibilities do exist. The alternative possibilities for positions in science education are not the first choice of most graduates nor were they the intention of most students as they began their doctoral programs. Yet the possibility of securing a position at a university level is very remote (425 doctorates for 17 projected positions or 1 in 25!).

If we can assume a "steady-state" demand for science educators, as depicted in our Present, then in the Future we must concern ourselves with the overproduction of doctorates who are unable to find use for their skills. We must cope with the ethical question involved in preparing educators for nonexistent positions, inadequacy of applicants from the same programs that emphasize science! Research skills were seen as the significant strength of 9 of the 22 surveyed programs and a formal component of 21 of the 22 programs. By content, nearly 40 percent of the inadequacies in an applicant's vita given by this same group of science educators was the lack of identifiable research skills in the applicant. The Past and Present suggests that we demand new skills in our graduates or prospective employees which we in part say we are including in their programs but which we find absent in the graduates of those programs.

Another view of the question of utilization is seen in the kinds of inadequacies that we as employers of science educators find characteristic of the graduates of today's programs. Table 6 includes a list of inadequacies given by faculty in the surveyed programs which they found in current applicants for the vacancies at university science education positions. This table contains a message. The discrepancy between what is considered a part of the program (Table 4) and what is identifiable in the vitae of science educators who are entering the profession is significant. As a profession we agreed that the Guidelines were an accurate description of what we believed should be in our doctoral programs. As pictured in Table 4, every program saw science (Guideline One) as a formal part of the doctoral program. Yet, lack of competence in this area was one of the most frequently mentioned inadequacies.

Table 5

Current Staffing Patterns of Science Education Doctoral Programs

Institution	Current Staff	Past Vacancies in 3 yrs.	Expected Vacancies in 5 yrs.	No. of Grad. per yr. 1972-75	No. of Grad. per yr. 1976-81
1	1+2 Pt.*	3	none	6-7	6
2	2	1	2	5	2
3	3	none	2	3-4	2-3
4	4	1	none	7	7
5	2	none	none	2-3	2
6	2	1	none	2	2
7	1+3 Pt.*	2	2	2	1-2
8	2+7 Pt.*	2	1	3	5
9	8	1	none	5	2-3
10	5	1	none	8	8-10
11	7	none	2	2	5-6
12	2+4 Pt.*	1	none	4	3
13	6	4	3	5	12-14
14	4	none	none	5	2-3
15	3	1	none	3	3
16	5	2	2	5	2
17	5	3	none	3	2
18	7	none	none	9	6-8
19	9	4	none	3	3
20	6+1 Pt.*	2	1	3-5	3-5
21	9+1 Pt.*	4	none	13	5
22	3	none	1	1	1

* Part Time Faculty

Figure 4

Priority of Graduates in Their
First Preferences for
Science Education Position

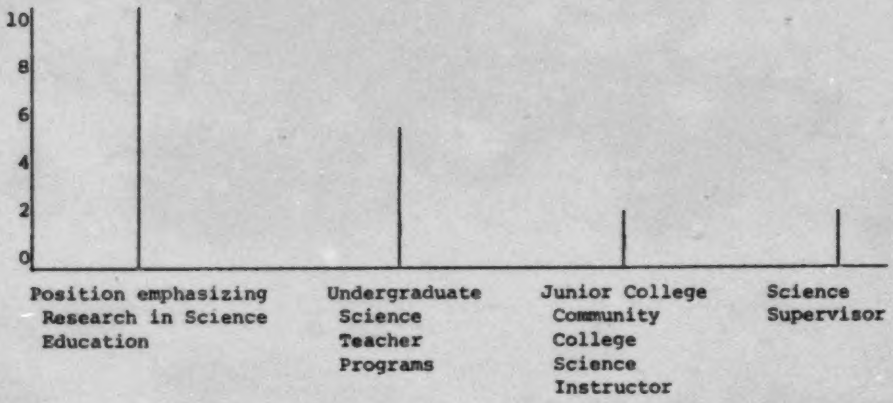


Table 6

Inadequacies in Applicants Vita for Science

Frequency Cited	Inadequacy in Vita
10	Lack of adequate or appropriate background in science teaching field. (Guideline One)
10	Lack of skills in conducting Science Education Research. (Guideline Six)
7	Lack of a definable research interest or effort or ability to write research papers. (Guideline Six)
6	Lack of experience in developing science curricula. (Guideline Two)
6	Lack of an accurate description of personal goals and accomplishments.
3	Lack of appropriate teaching experience.
3	Lack of ability to establish rapport with students. (Guideline Eight)

SUMMARY

Doctoral programs in Science Education have experienced a rapid and rich growth in the past ten years.

The Past view of these programs provides a picture of an emerging professional entity which had a major concern in establishing or maintaining credibility with science academic colleagues.

The Present view of doctoral programs suggests a picture of a profession that has gained more maturity and self-confidence. Rather than a concern for credibility with science areas, the emphasis is on competencies in instructional design, process evaluation and interpersonal skills. Such skills clearly require the ability to effectively interact with differing populations of people on instructional problems.

The Future provides a sobering appraisal of our doctoral programs in science education. What we describe as the collection of significant emphases of our doctoral programs is precisely what we find missing in the vita of candidates for our positions who are the graduates of these doctoral programs. Our preaching and practice in our programs do not match when we look at our graduates. The discrepancy between practice and intent is also illustrated in our screening of prospective students. The criteria we use are directed toward selecting those candidates we view as most likely to be successful in university positions--and yet the possibility of finding positions to match their training is very remote. To survive in the future, it is essential that we first clearly communicate the range of program emphases that our faculty can do well. Secondly, we must counsel with prospective students to enable them to specify these goals and then help them match a program to these goals. This personalization of doctoral programs is itself a key to the survival of a community of science educators. If flexibility, creativity, reflectivity and sensitivity is to be expected in our graduates, do they not have an equal right to expect us to demonstrate these same responsible characteristics as science educators?

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CHAPTER 6

IN PURSUIT OF QUALITY: RESEARCH ON THE EDUCATION OF TEACHERS

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> ". . . you must be exposed to things which you perhaps don't quite understand, for the more you think and ponder over these matters which may be somewhat difficult for you, the greater will be your capacity to live richly."*

INTRODUCTION

If there exists a central theme to the research that will be discussed in this chapter, it concerns the search for quality, a search in which we all seem in our own way to be involved. Although we are often motivated by different philosophies we all know with remarkable agreement when we have seen and experienced quality in teaching. But, how did it happen? How can we describe it? How can we bring it about more often? There are no direct answers in the research to these questions. Robert Pirsig speaks of the quality dilemma:

> Quality . . . you know what it is, yet you don't know what it is. But that's self contradictory. But some things are better than others, that is, they have more quality. But when you try to say what the quality is, 'apart from the things that have it,' it all goes poof! (65:178)

Caring is probably another ingredient that may be essential to successful teaching. There is a little in the literature on that topic, not how to produce a caring person - but on the importance people attach to it.

Quality and Caring: two recognizable but indescribable properties of effective teachers - hardly a good beginning for a chapter on research. But these attributes ought to be borne in mind as the underlying motif for that which follows.

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*Krishnamurti, J. Think on These Things. New York: Harper and Rowe, Perennial Library, p. 26, 1964.

A CONTEXT FOR LOOKING AT RESEARCH

Imagine for a moment that you could take a snapshot of a classroom. In that way you could stop the action to see what was there. A whole set of psychological and knowledge assessment measures administered over a short interval of time is something like taking snapshots with different radiation wave-lengths. Typically, we would find a teacher characterized by a unique set of personality variables, knowledges, interests, enthusiasms, hopes, expectations, fears, etc. There would be 25 or more students each with a unique profile of personality variables, skills, knowledges, enthusiasms, hopes, fears. All these people mix together daily in one room. If your snapshot turned into a movie you would see all kinds of interactions. Newton's third law comes to mind: for every action there is a reaction. In this case, however, the nature of the interactions remains largely unknown. The only thing we can be sure about is that variability within that classroom as expressed in what we would observe people doing and saying and feeling would be enormous. Teachers act on students and the students act on the teacher as well as on each other. It is a system full of motion, of energy, of feelings and sometimes of ideas. The people in the classroom change over time and with the situation. Variability characterizes the system. It comes from all the diverse people and events that make up the classroom. It comes, too, because the classroom changes over the period of a school year. Its beginning and ending characteristics are not the same. It might be convenient for people who like to categorize and count behaving, but it would suggest a loss of flexibility - and flexibility is probably one dimension of quality! Certainly, it is related to adaptability. What does flexibility, a desirable teacher trait, do to reliability and predictability and other valued attributes of research data?

If the within-classroom variability over time and in different circumstances is so great, think how much more variability would be added if you tried to compare behaviors in two or more classrooms over time.

In view of all the sources of variability in the school setting it is also not altogether surprising that the Coleman Report (24) and the Jencks et al. report (37) as well as others find teachers and schools account for only one percent of the difference in what students learn. Of course, the family would turn out to be a more potent predictor since it is the one variable which has some stability over the years. We have a sense that schools and teachers do make a difference - or why search for quality? Is it possible that the way cross-sectional studies aggregate variables and then project them through time has the effect of masking the teacher-school-administrator impact? Some support of this view comes from the research of Luecke and McGinn (47). They used computer models to challenge the idea that schools and teachers make so little difference. Luecke and McGinn posit various relations among the aggregated variables typically found in cross-sectional studies such as those by Jencks and Coleman. They simulate the longitudinal effects of the aggregated variables on achievement. The various simulations made under different assumptions show the impact of teachers, schools and local administrators to be much more pronounced than the cross-sectional studies indicate is the case. So, a search for quality may still be justified. The relative contribution which teachers and schools make apart from home background could be studied especially well if physics and chemistry were taken as the vehicle. These subjects are not generally a very prominent part of the home culture.

If there are all kinds of sources of variability loose in the classroom, it is not altogether surprising that people who are enamored of competency-based education have not been able to demonstrate stable relationships between specific competencies and particular kinds of student outcomes over protracted periods of time for all students. One way of teaching may help concept acquisition but block risk-taking during inquiry or create great dislike for the subject. High structure may be useful in certain classrooms or for certain students and may retard the progress of others [e.g., see Brophy and Evertson (16)]. What one student likes another may find boring (8). So, possibly quality in teaching is being able to help each of the students a teacher has in a particular year to recognize what is possible and to identify ways of realizing his potential.

Like the concept of quality, "helping people realize their potentials" is elusive. It does not sound like the language of research. What it suggests is that we need to discover what kinds of conditions help particular kinds of students to set and accomplish both immediate and long term goals.

As we consider the research discussed in the remainder of the chapter, think of the classroom as a dynamic system in constant flux and ask, what does it mean to be a teacher of quality? Also, ask what does it mean to be a good student - and is that how you know about the quality of the teacher? Can these two factors, quality and caring of the teacher and quality and caring of the student, be judged independently?

A DEFINITION OF QUALITY

As a result of its yearly search for an outstanding biology teacher the National Association of Biology Teachers (NABT) has gained extensive experience with the problem of evaluating the competence and effectiveness of biology teachers. Dieter and Hounshell (28) made a study of the priorities NABT judges attach to various factors employed in the rating process. One year they polled the 220 judges to find out how the judges, who came from different kinds of jobs, rated each of 111 factors. This certainly is one way to get at the question of what we perceive quality to be. The judges included secondary school teachers, public school administrators and supervisors, college and industrial biologists, and professors of education. Twenty-one factors of the 111 were rated as "usually important" to "always important" by the entire group. These 21 factors fall into three categories:

1. Intrinsic personal traits
    a. Interest and enthusiasm for biology
    b. Adequacy of self-concept

   c. Evidence of ingenuity
   d. Emotional poise and self-confidence
   e. Evidence of creativity
   f. Apparent interest in self-improvement

2. Student-teacher interrelationships

   a. Ability to encourage self-motivation in students
   b. Ability to inspire self-confidence
   c. Concern for personal involvement by students in learning activities
   d. Ability to facilitate student interaction
   e. Understanding of individual needs
   f. Efforts to provide for different student interests and needs
   g. Efforts to encourage students to develop higher level skills such as advancing hypotheses and theories

3. Skills and proficiencies of a science teacher

   a. Concern for student understanding of essential science processes and concepts
   b. Skill in use of a variety of materials and methods
   c. Thought-provoking laboratory experiences
   d. Classroom climate which facilitates learning

Nine factors were generally agreed upon as not being important. These included the number and kinds of course experiences or degrees; grades in college; location or size of school; years of teaching experience; teaching and managerial efficiency; participation in school, community or professional organizations; publications, honors or awards; appearance of classroom or laboratory. No students were included among the NABT judges.

Bybee (19) found elementary students rated adequacy of personal relations and enthusiasm as the two most important attributes of a good science teacher. So, while the judges are different in the Bybee study, there seems to be some congruence of outlook about what constitutes a science teacher of quality.

It is tempting to think of these judgments as to what constitutes quality in terms of some recent research on lateralization of brain function. The left hemisphere, according to current research, processes verbal information and the right brain processes feelings about what one hears. (See recent issues of the journal, Brain and Language.) One side of the brain pays attention to what is being said and the other side processes things about the speaker. There seems to be dual processing. The judges appear to be valuing many functions that may be predominantly right hemisphere based. Probably, the students do, too.

Although judges in the Dieter and Hounshell study did not consider teachers' grades in college to be an important factor, Kuhn (40) found that a significant positive correlation exists between undergraduate grades and the acquisition of certain teacher competencies. Smart people (in the sense of grades) are more likely to learn what you are trying to teach them!

PATTERNS AS INDICATORS OF QUALITY

In competency-based education prospective teachers learn pieces of behavior, what might be called skills and techniques. They get through the training program by demonstrating in some way or another that the requisite skills have been acquired. The assumption seems to be that if the teacher fills the classroom with these little bits of behavior all kinds of good things will happen to students. Even if we accept the assumption, the training rarely succeeds in helping prospective teachers to know when each kind of behavior is appropriate. The classroom is a dynamic system, a system in continuous transition. What cues "out there" ought to be connected as a basis for making decisions?

It is not entirely surprising that skills demonstrated in microteaching frequently do not find their way into the classroom (e.g., 13, 61, 72).

This writer believes the training problems are analogous to those we face when trying to teach people to read books. We are trying to teach people to read the classroom. In reading, for example, we teach word recognition skills but those skills do not seem to insure that a student can extract meaning from a paragraph. He still must face the problem of context as a source of information. That is, he has to come to understand patterns of words and sentences. In coherent text a context develops and progressively constrains the flow of meaning. So, too, a teacher must learn to read the classroom, to recognize whole patterns. In a way, the competencies they usually learn are like the words. There remains the problem of reading cues, making decisions and orchestrating the flow of things. There are examples of research which are relevant to this line of thought.

Gregory and Casteel (32) have described chains of interactions, patterns of interactions in mathematics and in social studies that are connected to improvements in logical reasoning and achievement. Research by Campbell (20) and Anderson (5) also can be construed as supporting the thesis that rather than discrete events we need to be examining patterns of interactions that facilitate particular kinds of outcomes.

Among other things, then, we need to learn more about how to read and attach meaning to the flow of ideas and feelings in the classroom. Jungwirth and Dreyfus (38) did a most interesting study in this connection. They reasoned that spontaneous teacher reactions to student statements could occur along four dimensions:

1. Content

2. Philosophy of science

3. Science as inquiry (methodology of science)

4. Methodology of science teaching

For example, if during a classroom discussion on plant physiology a pupil says, "In dry weather the plants close their stomata in order to save water," what is the teacher's response? Does he pay attention to the relation between water and the stomata? That would be a content response. Does he also recognize and respond to the anthropomorphism implicit in the phrase "in order to?" That would be a process response which relates to the philosophy of science. Does he pursue the question of how we know that stomata do what the student says they do? That would be a methodology of science response.

Jungwirth and Dreyfus believe that all three levels should be taken up but that teachers usually limit themselves to the content level. The two investigators identified twenty experienced biology teachers known to be able to respond appropriately along dimensions 2, 3, and 4 as well as on the content dimension. They developed two versions of a test to measure the adequacy of response of teacher-in-training and used the pattern of responses of the 20 teachers as the external criterion. Next, they designed a decision-making course that included lectures, demonstrations, discussions and structured classroom visits. In a pre-post test design they found that preservice teachers made the most gain on inquiry (dimension 3) and the least on philosophy (dimension 2). The investigators raise the general question of whether it is possible through some kind of training to change teacher priorities.

It seems to this writer that the line of research begun by these two investigators is potentially very productive since it suggests a substantive approach to the teaching of science process. Teachers, especially content specialists, would learn to listen and respond to student statements on several levels. This involves a kind of reading of the idea flow. If there are multiple dimensions along which high school science teachers could make responses and give information, they probably should be sensitized to the possibilities. Therein lies a training problem in need of some research.

There exists some indirect evidence that preservice students who work in classrooms are more likely to learn the context and so to apply skills appropriately than are students who have to learn the skills through peer teaching. In a study reported in 1968, Steinbach and Butts (81) compared the merits of teaching peers with teaching children. They found that pacing skills and some questioning techniques were only developed by those teaching children. Systematic feedback from experienced teachers helped improve lesson clarity and pacing.

Lahnston's (41) work also supports the position that practice of skills with children ought to be part of the training process. Lahnston used pupils as a criterion of intern teachers' effectiveness. He found that pupils taught classification skills by field-based interns (four days a week in classroom) learned more than they did from interns who had only one day a week of observation and supervision in classrooms accompanied by other educational activities at the university. Jacobs (35) wondered whether a program of structured observations and analysis of live teaching situations would assist observing teachers in acquiring new responses or in modifying existing patterns. The teachers in the treatment group obtained more pupil talk but not more variety in pupil participation. Apparently, active participation or practice with children improves the probability that a technique will transfer successfully to the classroom.

These three studies, taken together, suggest that prospective teachers who learn techniques and use these techniques with students are more likely to employ the behaviors appropriately when they become teachers. Observation is not enough. Practice with peers is not enough. Practice with children is not enough if there has not also been explicit instruction concerning desirable techniques. Feedback from experienced teachers and modeling by such teachers of relevant patterns are also necessary but not sufficient ingredients of an effective program.

Although in many respects we are lacking in theory to guide us in what we do, where some well developed and tested theory exists and has potential application in science, it should be given a try.

All three of the studies described above can be interpreted in terms of observational learning theory. Koran (39), who has done a considerable amount of research on the effectiveness of various types of models for teaching prospective teachers new behaviors, remarks that early exposure to practice constitutes a form of modeling. His paper on methodological problems and issues in changing behavior makes a plea for science methods instructors to become familiar with social learning theory and observational learning theory, especially as developed by Bandura (10).

Where are we at this point on the quality issue? If the NABT people are right about what constitutes quality, we need to teach people how to respond on many levels to what goes on in the classroom. There appear to be left brain and right brain considerations. There are dimensions related to content and process in science. The problem seems to center around helping teachers to be effective classroom readers. The Jungwirth and Dreyfus study suggests that training apart from considerations of curriculum is probably inadequate. The next section considers how curricula and instruction may bear on our pursuit of quality.

RELATIONSHIPS BETWEEN CURRICULUM AND INSTRUCTION

From the new science courses for both elementary and secondary students introduced during the 1960's there emerged a training question: Aside from changes in course content were changes in methods of teaching required? In general, the writers of new programs wanted students to engage in more inquiry. They did not want teachers to tell pupils all the outcomes of experiments. They wanted more of the responsibility for getting information and interpreting and explaining results to be placed on pupils.

Pausing

In a set of studies carried out over a seven year period, Rowe (69, 70, 71, 72) found that inquiry related behaviors of elementary students could be substantially improved if teachers simply increased the amount of time they waited for a student to begin a reply to a question and lengthened the period of the pause after a student makes an initial reply. She found that typically teachers wait one second, after they ask a question, for a reply to be begun. If no response begins in that interval, the question is either repeated, rephrased or some other student is called upon. When a student replies, teachers typically make their next move within 0.9 seconds. First, with small groups of children and later with whole classes, Rowe began a series of studies to determine what would happen if these two wait-times were lengthened to three seconds or more on the average. Nine student variables changed in response to the altered teacher wait times. Only four are especially relevant to the discussion in this section:

1. The length of students' responses increased, in some cases by more than a factor of seven times.

2. The incidence of speculative thinking increased as did the number of alternative explanations.

3. The number of inferences supported by evidence increased.

4. Children asked significantly more questions and suggested more experiments to obtain answers.

Notice that in these four outcomes student behaviors changed. The interactive conception of the classroom which undergirds the presentation in this chapter suggests that the subsequent decision patterns of the teachers will have to change. The teachers changed pausing behavior. In response the students spill out a greater variety of moves. Now what does the teacher do? The context reading problem, so to speak, has become more complex.

Rowe followed some of the teachers who had achieved three-second criterion wait-times during micro-teaching sessions into their classrooms. She observed them at intervals for periods ranging from 12 weeks to one academic year. Early in the third week teachers began to regress back to shorter wait-times and to express considerable anxiety about the way they were functioning. This change seemed to be brought about by their altered role. Students and teachers were taking different responsibilities. Teachers went through a period in which they could not decide how much and when to intervene in a student discussion. Students, for their part, were learning to use their instructors in a different way. This was reflected in the change in number and kinds of questions they asked. Rowe remarked that if teachers were able to recognize what was happening, to talk over their feelings, and if they received some encouragement during this brief transitional period, then the criterion wait-time behaviors tended to be stabilized. The period of indecision seemed to last about two weeks.

Rowe's data about changes over time illustrate the importance of in-vitro long term studies. Most investigations are of too short duration to determine how well new skills are stabilized and how they work out in classrooms over the long haul. Some new procedures produce extensive changes in the dynamics of the classroom with the result that they require shifts in the way students and teachers interact. In support of the dynamic conception consider another finding in the Rowe studies. Teachers who had been on a prolonged wait-time schedule gradually altered their questioning strategies without specific training. Students said different things. Teachers had time, as did students, to think about what was said. Although the total number of questions decreased there was a relative increase in the number of probing questions asked by the teacher as well as questions that called for clarification and extension of ideas. Far too many research studies encapsule too little pieces of time. For that reason we fail to understand the classroom evolutionary process. It is no wonder so many apparently promising techniques turn out to fall in the class of non-viable mutations!

Rowe's research also illustrates how solution of one problem generates another problem. Once a research finding suggests a procedure that might enhance some aspect of the classroom condition as, for example, changes in pausing behavior, a training procedure has to be developed. An effective training procedure gets the job done as rapidly as possible, has a high percentage of success, and wins support from the people being trained. That is, the invention and testing of new training procedures may be regarded as a new problem. With respect to the wait-time training, for example, Rowe followed a training procedure that involved three micro-teaching sessions. In the first session, the trainees heard about the variable, tried to achieve criterion pauses with a small group, listened to their tapes, tried again and listened. Sessions two and three were similar. Seventy percent of all the people that eventually went through this sequence achieved criterion. Thirty percent, however, did not. Rowe considered a 30 percent failure rate and the need for six hours of training to be unsatisfactory. There are other procedures such as modeling she could have tried. The point is that the training phase itself becomes a locus for inquiry.

Raymond (67) for example, used a video-tape model to teach silence plus a set of non-verbal, largely reinforcing cues. After viewing the model, preservice teachers in the experimental group tried out the behaviors on peers, observed the results on video-tape and tried again: a teach-reteach procedure coupled with modeling.

She reported, not surprisingly, that students given this training exhibited more of the non-verbal reinforcing cues during practice teaching than did the control group. Her study (which had some methodological problems) shows some transfer, but we do not know how much. She works on two assumptions: the behavior once demonstrated will be maintained; peer practice will be an effective device for learning and properly using the pausing and reinforcing techniques. These assumptions are not warranted.

Arnold (7) found that whether teachers asked simple or complex questions their wait-time was the same - it was short whether the questions were hard or easy. The next section examines some of the research that relates to improving teacher questioning. Sadly, there exists nothing current that this writer could find concerning ways and means of helping pupils to ask better questions. Many teachers today receive specific skill training on questioning techniques. In recent times there has been no corresponding push toward teaching pupils to ask various kinds of questions.

Questioning

One long term effect of increases in wait-time relates to questioning. Teachers' question patterns became more varied than they were prior to training (69, 70, 71, 72). We have no basis, however, for deciding what patterns are optimal. Nevertheless, there is evidence to suggest that a relationship exists between achievement and the kinds of questions asked. Generally, better achievement is related to a greater incidence of higher level questions, questions that call for reasoning. In chemistry, Aagaard (1) had five teachers ask predominantly memory questions. He contrasted student achievement in those classes with achievement in six classes where teachers asked more higher level questions. Yoeh (90), who also worked in science found that pupil test performance related to skill in questioning coupled with appropriate reinforcement of student responses.

The relation of question level of achievement has recently been called into question by P. H. Winne at the Stanford Center for Research and Development in Teaching. In a review (87) of 12 recent studies which related teacher questioning behavior to student achievement, he reports that because of methodological errors, the conclusion that a relationship exists is largely unwarranted in nine of the classes. This would apply to investigations by Lynch et al. (48) in which factual recall and concept mastery in science were the independent variables; to Aagaard (1) who provided scripted questions in chemistry; and to Martikean (50) who examined the effects on achievement of higher cognitive questions as contrasted with knowledge questions in third and fourth grade science.

Winne complains, as does this investigator, that most of the studies on questioning are of such short duration that we do not know how transitory the results are. The same complaint applies to well over half the studies described in this chapter.

At this point it may be well to raise a question about questioning studies. Not many of the investigators have controlled for or in some way accommodated their analysis to the differences in rewarding behavior that their subjects probably exhibited. In short, there may be an interaction between rewarding and questioning behaviors. The separate and conjoint effect of these two factors ought to be investigated.

In view of these studies and others, it is not surprising that methods teachers have taken an interest in teaching students to ask a wider variety of questions and to shift their emphasis away from cognitive memory to higher level questions. But just as the wait-time variable is not easy to learn so the business of teaching people to question students more effectively has its problems. Blosser (13) found that preservice students who received training on question-asking techniques exhibited more varied strategies than did students who had not had special training. She went on to find out when in the education of preservice students it would be best to give the training. Those who seemed to benefit most from the training were those who received it over a period of two quarters, just prior to and concurrent with the practice teaching period.

In contrast to Kuhn's (40) finding that higher aptitude students are more likely to learn the training competencies one is trying to teach, Blosser found that the development of questioning skill did not appear to be significantly associated with intelligence, sex, personality type or educational set. Blosser's study also calls to mind the remarks made earlier in this chapter about the utility of learning a skill in the context in which they are ultimately to be practiced. Blosser says that where the cooperating teachers also modeled the desired behaviors the probability that the preservice teacher would also exhibit appropriate questioning strategies was higher. Success in a micro-teaching situation did not seem to ensure that the student would transfer the skills to the classroom. Blosser's study reminds us of how important the supervising classroom teachers are as a source of example for new teachers. If the classroom practitioner exhibits the behaviors that the prospective teacher is supposed to be learning, then the prospective teacher is more likely to value the behavior and to use it appropriately.

In another study of the impact that training in questioning has, Adhikary (2) showed that the trained group asked more convergent, divergent and evaluative questions than did the untrained group. There were two unfortunate aspects to this study. The trainees were tested using each other, not classroom groups. It is doubtful that this training will transfer to practical contexts. Another finding of Adhikary prompts concern. The experimental group asked more questions. Now, if they are asking more questions and the questions are of a more difficult nature, what can possibly have happened to the time for thinking, to the wait-time?

Arnold (7) reported that whether teachers asked simple or complex questions, their wait-time was the same. Can that be sensible behavior? What we confront here is the need for researchers to begin to see the importance of tying together variables into fruitful patterns. Wait-time, questioning patterns, rewards are probably all related. We must now begin to investigate those relationships with experimental rather than correlational procedures. What constitutes quality? If teachers learn to ask more questions, to ask harder questions and to ask them faster, what will happen? Is it unreasonable to guess that to foster productive inquiry on the part of students, teachers need to ask fewer questions, to ask more thought provoking questions, to give students time to think and to reduce overt verbal rewards? It is the pattern which makes an impact.

Lalanne (42) suggests that we find other more conversational ways of exchanging ideas with students. Questions, especially when they come by the hundreds each day, engender resistance and evasion. From early childhood we learn that questions are often the prelude to trouble. Rowe (69), for example, found that if teachers began a question with, "Why . . .," elementary children were much less likely to give a satisfactory response than if the same information were requested in some other form. "Why " calls for justification. What the teacher usually wants is explanation:

> Teacher. Why did it do that?
>
> Student. It just did, that's all.
>
> vs
>
> Teacher. What do you think might have made that happen?
>
> Student. I don't know. It could be the bubbles.

We need to find more diversified forms of verbal exchanges between teachers and students.

If we stick to the pattern paradigm it will change our outlook in still another respect. Many writers complain that teachers ask a disproportionate number of low level, largely memory testing questions. But a larger number of information questions may be appropriate in some contexts. If, for example, a teacher asks a higher level question calling for hypotheses of some kind and receives inadequate responses, then it may be entirely appropriate to quickly check whether suddents are in possession of the requisite information. The context, in short, determines what pattern of exchange is probably appropriate.

Winkeljohn (86) wanted to get teachers to ask more open-ended questions and not to dominate the talk. She found that teachers in her sample did not change their behavior after exposure to a set of inquiry-oriented laboratory experiences in which the instructor modeled the desired behaviors. Teachers still permitted little initiation of activities or discussion by the students. Most of the questions were cognitive memory rather than speculative. Open questions were almost non-existent and the proportion of substantive questions was low. Clearly, there is still a need to search for more effective training procedures that contribute to changing patterns of behaviors.

Interaction Analysis

One popular procedure for getting teachers to provide more opportunity for student inquiry, speculation, theorizing, etc., has been to have them learn some version of Flanders Interaction Analysis. The results of these efforts in terms of student achievement in science are not consistent. For example, Almase (4) found that a group of 20 experienced biology teachers did exhibit a more indirect pattern as defined by Flanders but did not improve in the use of behaviors which would stimulate, support, or reinforce inquiry. With a sample of 10 BSCS teachers who learned the Flanders system, Wright (89) compared verbal behavior in inquiry and non-inquiry settings. Wright distinguished between teacher-centered inquiry and student-centered inquiry. The total proportion of teacher talk decreased throughout the program but oddly enough became more direct in student-centered inquiry than in either teacher-centered inquiry or in what might presumably be a predominantly lecture situation. Wright thinks this shift can be explained in part by an increase in student questions directed to the teacher. In Wright's study we see how the situation can influence the pattern of interaction. Consider Wright's findings in connection with the next three studies to be described.

In a student teaching situation Strawitz (82) had 13 preservice teachers randomly assigned to one of two conditions: one group received feedback based on an interaction system while the other studied audiotapes of their classes. While no difference was found between the two groups with respect to attitudes toward teaching, the interaction analysis group showed more acceptance of student ideas, allowed more student talk, did less fact telling and were generally less directive. With a group of experienced junior high school science teachers, Baker (9) found that exposure to interaction analysis resulted in more indirect verbal behavior in the classroom and a correlated increase in student initiated participation.

It seems to this writer that the use of interaction systems which have components whose relevance specifically to science has not been properly evaluated may, over the long run, do more harm than good. Two examples come to mind. Before the research on wait-time, people interpreted a high incidence of the tenth category of Flanders (silence or confusion) as undesirable. But the research on wait-time leads to a different interpretation. Consider also how much the Flanders system encourages teachers to regard students. But, is that appropriate for science? Rowe (72) has suggested that high reinforcement schedules may be detrimental to the kind of risk-taking behavior that characterizes inquiry. Modern science programs work on an intrinsic motivation model but the Flanders system does not include that assumption, quite the contrary.

There is a persistent tendency in science education to teach a collection of techniques without careful examination of their conceptual or theoretical relation to the goals of science or to a theory of inquiry. With respect to reinforcement in the context of inquiry teaching, we need much more careful delineation of what kind helps and what hinders and what form it should take and when is it best administered. For the moment, until the problem is more clearly defined and researched, we would probably do well to minimize overt verbal rewarding during either teacher-centered or student-centered inquiry. On the other hand, teaching people how to produce a better I/D ratio has been known to lead to better student achievement as, for example, Wolfson (88) found in eight classes of high school chemistry and six classes of general science.

The usefulness of some observational system specifically adapted for science can be inferred from an exploratory study by the Lawlors (44) who exposed 72 undergraduates to two ten-minute video-tapes of a small group of children working a science task. The prospective teachers were then asked to rank the children on perceived ability. There was remarkable unanimity of the rankings. The Lawlors tried to find out what observations led to the quick rating of the children. These prospective teachers mostly stated inferences which were unconnected to observations. By learning a specific observational system they might be protected from unwarranted conclusions.

We are faced with the necessity of making more explicit the conceptual ties between our philosophies of science, our conceptions of what constitutes productive inquiry, and the psychological dimensions of science education. Obenauf's dissertation (59) which deals with questions of philosophy and psychology might constitute a start in the direction of making these relationships more explicit.

We can infer from much of the research described thus far that science educators have been pushing for more open classrooms and for teachers serving as consultants to their student colleagues. Conklin (25) argues against this point of view. He puts more responsibility on the student. According to him, learning is a personal kind of process regardless of the treatment conditions. There are stages in the development of pupils which are invariant and students need help in getting from one stage to another. Regardless of the presentation characteristics the learner must still break down and organize knowledge in his own way. The learner still has to do the integration. Under any system each learner is still personally responsible for the skills, feelings, and understandings he develops.

The pupil, Conklin argues, must learn to behave in conformance with the canons of reasonableness and folkways. He does not have to agree, according to Conklin, but he does have to know what they are. He describes the teacher as a choreographer of student learning. Although Conklin does not explicitly discuss it, personality variables may also influence how teachers and students interact, what kinds of activities interest them, how they process information. In a later section the research which relates to personality and modes of instruction will be discussed. One more comment concerning observation systems should receive attention before moving on to prescriptive teaching.

There is another use of observational systems which did not appear in the science education literature reviewed here but nevertheless deserves some attention at this point. Each new science program has some unique characteristics and some characteristics that it shares with other programs. In her study of Head Start programs, Stallings (80) developed a procedure for measuring the degree of implementation of specific Head Start model programs. Once she had the observational model for each program, she could compare the degree of implementation between schools and she could relate the degree of implementation to achievement measures of various kinds. The procedure has interesting potential use in science education. Suppose we could measure the degree of implementation of a program. We could relate that to achievement. Within a particular program the data could be given back to teachers. This would reinforce those whose implementation is high and would provide specific helpful information to those whose level or degree of implementation was low.

Self-Directed vs. Instructor-Directed Courses

So far, the discussion has been directed to studies that examine student-teacher interactions. There exists a trend, however, toward designing courses in such a way as to give students more choices, more freedom to make their own decisions. Presumably, this will prepare them for the time when they must make decisions in teaching and hopefully will encourage them to give some of the same kind of freedom to their own students. The results, however, seem to be inconsistent. Wideen and Butt (85) gave one group of prospective elementary teachers in a course considerable freedom to make decisions. In the contrast condition the instructor directed the course and made most of the decisions. Both groups were given the same resources and objectives. The two investigators found no main effects on the learning and attitude measures they used. Magnus (49) conducted a similar study in a physical science (chemistry) course for undergraduate elementary education majors; but in contrast to the results obtained by Wideen and Butt (85), the self-directed study group out-performed the teacher-directed group on the criterion content measure. Sundberg (83) found that in a physics course for elementary teachers, the instructor-directed groups learned more than did students in a laboratory curriculum of self-directed activities and more than did students in a manual-directed program of study. The difference still existed in a second post-test administered well after the first post-test.

In a different but related view, consider what seem to be conflicting results. Merkle (52) reported that elementary teachers in a six-week inservice course learned more about pendulums through an activity program than by reading about pendulums. However, the same study conducted in an eleven-week course showed no difference [illegible] learning between the two treatment groups. Mouser (57) presented measuring processes to elementary preservice teachers by what [illegible] characterized as abstract and applied modes of instruction. More competence in measurement was gained from the applied mode.

Chrouser (22) compared the effects of an outdoor biology program with an indoor laboratory course for elementary teachers. Both groups did as well on measures of biology learned but for some reason which he could not explain, students in the outdoor group gained a somewhat better understanding of science as a social process!

When the results of research are so mixed, it is time to ask why. Do the results suggest that different kinds of contents need to be presented differently? None of the investigators performed an aptitude-treatment interaction analysis. This procedure might have shown which students profit most from which treatments.

New Curricula Plus Prescriptive Teaching

In an interesting experiment where he followed students into their first year of teaching, Perkes (63) taught preservice teachers the Elementary Science Study (ESS) program and accompanied this instruction with training in the style of teaching that goes with ESS. Teachers with this training continued to use more indirect behaviors in their first year than did those for whom behaviors were not specifically prescribed. Perkes remarked that the results of his study suggest that it is useful "to require students to adhere closely to pedagogical directives of a guide."

In the Perkes study we see the conjunction of a number of variables. If teachers learn the kinds of behaviors that are relevant to a specific instructional context and also learn the content well enough that it is not a big problem, then the likelihood that they will provide desirable instruction in science greatly increases. If we had an observational system suitable for each program as Stallings did for the Head Start, we could compare the level of degree of implementation to different kinds of teacher training procedures.

In connection with perceptions of teachers, Berger's (12) attempt to distinguish between the impact of training and the impact of experience on teachers' role perceptions is interesting. He identified four groups of teachers: (a) those not exposed to Science Curriculum Improvement Study (SCIS); (b) those not yet exposed but about to begin a training institute; (c) those who had completed a two or four week institute, and (d) those with an institute plus one year of experience teaching the SCIS curriculum. He used a self-report inventory called a Predicted Role Measure (PRM) to assess changes in perception. Teachers with SCIS training differed from those with no training. Teachers with one year of experience teaching SCIS did not differ from those with SCIS training but no experience teaching the curriculum. In this research we can see some support for the conclusion that Perkes came to, namely, if there are teaching imperatives attached to a particular program and if they are taught in conjunction with the curriculum the new roles may be learned fairly early. Had Berger obtained a sample of teaching by each group to find out whether there is a correspondence between role perception and reality, the validity of his findings would be greatly increased.

From results of both the Perkes and Berger studies we might also be prompted to ask whether there is evidence that exposure to a new curriculum does in fact lead to changes in teaching style.

Giese (31) found that exposure to Intermediate Science Curriculum Study (ISCS) training which emphasized both content and process produced change in teachers' knowledge of process but not in their attitudes. In addition, he took samples of the teaching done by the 34 junior high school teachers in the study and found that cognitive characteristics and knowledge of the ISCS more strongly predicted behaviors than did attitudinal characteristics.

Southerland (77) followed a group of SCIS trained teachers into the classroom and found that teachers' styles did change toward a more indirect form as defined by Flanders. Attitudes toward science also improved. In a study done three years earlier, Bruce (18) obtained similar results with SCIS, as did Moon (55). Both these investigators reported that teachers asked more high level questions after their exposure to the SCIS. Orgren (60) also reported that teachers who took part in a new earth science program changed their behavior in response to the demands of the curriculum. Pempek and Blick (62) found elementary teachers' attitudes changed after training in a new science program and teaching it but there was no significant change in their teaching behaviors. The attitude changes were most pronounced for teachers with the poorest content background. The evidence to date concerning the impact of training in a new curriculum suggests that teachers with the least knowledge make the greatest gains.

To be effective, it appears that training in the content of new curricula should be accompanied by careful delineation of the kind of teaching which is suitable for that program. Research by Bridges, Bingham and Green (17) provides further support for this statement. They measured performance of pupils in the DISCUS program for underachievers as part of their attempt to separate the effects of curriculum per se from the teacher training component. Trained teachers compared to non-trained teachers provided more student involvement, less external discipline control, and more student-centered instruction. Trained teachers lectured less and used significantly more concrete image provoking behavior than did non-trained teachers. Their pupils also achieved more.

As a method for evaluating the effects of a College Cooperative School Science program which featured SCIS, Lawlor (43) monitored the attitudes of elementary pupils in grades two through six toward science as a school subject. Attitudes of students exposed to SCIS were more favorable than were attitudes of students who did not receive the SCIS program. Lawlor reported that pupils of teachers who used SCIS but had had no training did not react as favorably as did those who had received instruction from trained SCIS teachers. Here, we can infer again the importance of giving teachers specific instruction on the way in which a particular curriculum is meant to be presented. The impact of the curriculum alone is not as great as the curriculum plus training. Coupled, the two appear to produce considerable changes.

PERSONALITY CHARACTERISTICS

Just as students have preferred ways of learning, so, too, teachers have preferred ways of teaching. In recent years several kinds of personality measures have been shown to be correlated with teaching styles, and with preferences for particular ways of processing information.

Taylor (84) reported that personality characteristics of activity-centered teachers differed in some respects from those of text-centered teachers. Taylor gave both groups the 16 Personality Factor

Questionnaire. Activity-centered teachers tended to be more self-sufficient, more affected by feelings than were their text-centered counterparts. At the same time they were more suspicious. Activity-centered teachers were also better at recognizing inferences and assumptions. Campbell and Okey (21) noted that preservice teachers who scored as "open-minded" on the Rokeach Dogmatism scale were more likely to incorporate basic science process skills in their lesson plans than were their more "close-minded" peers. A study by Pizzini (66) who also used the Dogmatism scale implies that experiences such as those in the University of Iowa UPSTEP program can result in desirable shifts on the Dogmatism scale. He regarded shifts on the Dogmatism scale from "close" toward "open-minded" as well as certain changes on the Tennessee Self-Concept Scale as desirable in terms of the goals of the UPSTEP program.

A study by Cook (26) suggests that knowledge of the degree of open-mindedness prospective teachers have can be used as a basis for differentiating instruction. Extended experiences with teaching science to children resulted in a significant improvement in attitude toward science for "close-minded" students but not for "open-minded" students. Furthermore, he reported that scores on the Dutton-Stephens Attitude Science Scale and the Rokeach Dogmatism scale were uncorrelated. There is no necessary connection between one's level of open-mindedness and one's attitude toward science.

Armstrong and Ladd (6) set out out to produce change in the value of two personality variables. They found that elementary teachers in their sample tended to score more as externals than one would expect from studies of other college students. Rotter's measure of internality-externality originates from social learning theory. It seeks to measure the extent to which a person believes he can influence the world around him so that rewards will flow his way. An internal person believes that what he does or how he acts relates to the good and bad things that come his way. Externals are more disposed to explain things that happen as due to luck or to the whims of powerful others. An external feels less responsible for outcomes. The investigators also gave the Inner-Direction Scale of Shostram's Personal Orientation Inventory. Armstrong and Ladd hoped to produce a shift toward internality and toward inner-directedness. (They found no significant correlation between the two measures.) In micro-teaching they substituted peer evaluation and supervision for the more usual faculty appraisal. In comparison with the control group, students who participated in rotating peer supervision did shift toward more internality as measured by Rotter's instrument. This group did not show a corresponding change on the Inner-Direction Scale of Shostram's Personal Orientation Inventory. So, while the use of peers in micro-teaching seems not to be productive if students are to learn the way to function in a classroom, their employment as commentators and supervisors may have some beneficial effects. Whether or not the shift on the Internality-Externality measure has any concomitant teaching value still remains unknown. A study by Janzen and Beeken (36) suggests that internals may exert more control in the classroom than do externals.

In a study of personality types Isabel Briggs Myers (58) in Pennsylvania and Mary McCaulley (51) in Florida have made some fascinating discoveries that ultimately relate to curriculum and instruction. "The Myers-Briggs Type Indicator is concerned with the valuable differences in personality that result from the way people perceive and the way they judge." (58:1) There are four scales on the instrument: (a) Extraversion-Introversion (EI); (b) Sensing-Intuition (SN); (c) Thinking-Feeling (TF); (d) Judging-Perceptive (JP). It is possible to identify 16 personality types. Society has need of all types. People who are ST or SF focus their attention on facts while NF and NT types are more interested in possibilities such as new projects, or new truths that might be found. ST's tend to be practical and matter of fact and to use facts as a basis for thinking. ST's are sociable and friendly and are concerned with the human dimensions of events. NF's are enthusiastic and insightful. NT's are logical and ingenious, often theoretical and relatively less interested in the human element. Myers and McCaulley report that each profession tends to have a modal type. For example, businessmen, lawyers, economists and surgeons are mostly ST. Nurses, G.P. physicians, welfare workers are SF. Teachers, some researchers, psychologists are NF. Research scientists, pathologists, management and security analysts are NT.

Fifty-six percent of the population falls in the extrovert-sensing (ES) category. These are the pragmatists in society. For them, knowledge is important for practical use. Only 6 percent fall into the introvert-intuition (IN) category. These people are the "academics" in society. To them knowledge is important for its own sake. McCaulley points out that most of the curriculum development in science and mathematics that went on under NSF aegis was done by IN's. In other words, a group of people whose preferred ways of knowing and valuing are represented by a small segment of society did the planning for a group whose characteristics were and are entirely different. Most of the teachers and students for whom the programs were meant, do not go about apprehending the world the way this 6 percent segment does. Myers and McCaulley have also shown that professors tend to fall in the IN or EN categories while the majority of their students are ES's. IN's and EN's prefer abstractions, possibilities, etc. For them, knowledge for its own sake is important. The ES's are more "here and now" oriented. They care less about theory. They want practical information.

Huston's (34) study lends support to the preferences as described by the Myers-Briggs Type Indicator. In a study of value orientation of 39 Canadian chemistry teachers and their students, Huston found that teachers preferred theoretical ideas in chemistry while their students expressed more interest in humanistic and technological implications.

How would information from the Type Indicator help us to tailor our preservice and inservice education programs as well as our curricula? We need research in this area. Certainly, one basis for conflict between instructors and students stems from the differences in the way they perceive and judge, and react. If teachers and older students (seventh grade and above) had an understanding of their profiles they might find more productive ways of working together. Knowledge of Myers-Briggs types could conceivably provide a basis for individualizing instruction as well as for the construction of effective work groups. In any case, it is tempting to think of each discipline as a kind of unique species that occupies a specified ecological niche. Different personality types inhabit different niches. In each niche there are a few variants. Every biologist knows that survival of the species depends, in part, upon those variants. Are there enough of them or has the species become too homogeneous?

McCaulley remarks, by way of example, that scientists who go before Congress act as though political and economic decisions are made on strictly logical, rational considerations. The scientific community has in it too few people who are capable of other modes of persuasion. She suggests that support for research will continue to decline unless more scientists are able to function more effectively as teachers and persuaders in the political realm.

What relationships exist between personality and attitudinal variables? Few researchers have put these sets of variables together. In 1969 Shanks (74) examined the relationship of science knowledge and personality to success in science teaching. The high science concept achievers among his preservice elementary teachers demonstrated an analytical cognitive style, were goal-oriented, self-directed women with a firmness of character and above average intelligence. But this group also produced the lowest scores on the Elementary Teacher Scale of the Strong Vocational Interest Inventory. They were impatient, stubborn, demanding, imaginative, and more emotionally insecure than the comparative group. Low achievers of concepts of science demonstrated a non-analytical cognitive style. They were described as lacking in self-discipline and self-confidence and were of more average intelligence. They were also characterized as serious, sincere, industrious, and responsible. Unfortunately, we do not know from this investigation by Shanks how the two groups perform in the classroom. Which aptitude and personality variables, if any, really matter in the classroom?

In 1969 Bruce (18) reortedly found a relationship between scores on a science process test and the Minnesota Teacher Attitude Inventory. The science process scores were also positively correlated with higher level question asking by the 15 SCIS teachers in his study. Personality variables did not exhibit a significant relationship to process or questioning.

In a more recent study reported in 1975, Perkes (64) examined relationships between prospective teachers' background and their sensed adequacy to teach elementary science. Since people tend to avoid situations which have negatively reinforced them in the past, Perkes reasoned that if teachers had had a hard time in science they might well prefer to teach other subjects. He found a relationship between reported bad experiences and sensed adequacy to teach science. Students who had taken modern high school science courses exhibited a better grasp of process. Perkes remarked that we have to find means to build in success in science if teachers are to regard it more positively. None of the personality variables that emerged from the Omnibus Personality Inventory bore on the science questions.

ATTITUDES

Attitudes toward science or about science have been a central concern of investigators for many years. A few recent studies will be discussed in this section. Some questions of attitude theory and measurement are raised at the end of the section. These are prompted by the apparently inconclusive findings of the research reviewed.

In a study of 12 first through sixth grade teachers taking part in an inservice science course and their 313 pupils, DeGroote (27) reported that, in general, the attitudes of both pupils and their teachers improved over the six-month interval. DeGroote said that the teachers who sought the most help had fewer years teaching experience, fewer college credits in science, and did not prefer to teach science. There was no analysis of content for the purpose of ascertaining which parts of the course contributed most to changes. Shrigley (75) reported that for a group of 92 preservice elementary teachers the correlation between knowledge of science and science attitudes was non-significant. Ninety-four percent of the variance on the attitude inventory had to be accounted for by something other than science knowledge.

In a study of two National Science Foundation Summer Institutes, Spradlin (79) tried to find out how the attempt to improve content knowledge of participants altered perception of self and the subject. There was an apparent negative effect on participant attitudes immediately following the institute; however, this effect had changed one year later. The attitudes of participants improved but they showed no more maturity of their concerns about teaching. In an earlier report Spradlin (78) described how the classroom behaviors of secondary teachers who had been in a summer NSF Institute shifted in the following year. Participants exhibited a more student-centered and indirect style. Both the participants and their pupils, however, failed to report any shift in attitudes toward their science course.

After an NSF biology summer sequential institute, Dyche (29) found NSF teachers carried out more laboratory investigations than did a group of controls. All the participants felt they gained extended insights into teaching as a result of their interactions with the other participants in the program. Here, we may find a clue to the question of how best to expand the teaching awareness of experienced teachers, namely, put them in a situation where they have reason to exchange information and ask questions of each other. Teachers reported that this chance to learn from each other was a very valuable part of the program.

Mitchell (54) evaluated the effects on interest, knowledge, and attitudes of two treatments given to a group of prospective teachers: (1) an open learning environment; (2) a formal lecture-discussion approach. A group which received no training served as a control. There were no main effects. Changing attitudes is no easy matter. For experienced teachers, these are likely to be firmly established. Hulleman (33) remarked that the 25 teachers in an inservice environmental education course showed no better attitudes toward or understanding of science after training than did a control group which did not have the training.

Mitchell's (53) investigation will probably be discouraging to people who feel there are pronounced differences in behaviors and feelings which emerge from exposure to open, humanistically oriented courses as opposed to a didactic approach. Mitchell sought to assess the effects of two different instructional strategies in teaching science methods on selected attitudes and perceptions. He also wondered what effect the 30 prospective elementary teachers in his study would have on children's perceptions of teacher behavior variables of warmth, demand and utilization of intrinsic motivation. (Recall that students in Bybee's study and judges in Dieter and Hounshell's survey considered these factors to be at least as important as knowledge of science.) One group of undergraduates received intensive instructional sessions specially designed to affect attitudes and perceptions toward science teaching. The other group's instruction took the form of the usual didactic approach. Mitchell found no differences on any of the indicators he used. There was some suggestion that those trained in an open-learning environment responded somewhat more positively to instruments measuring open-mindedness.

With a group of 80 preservice elementary teachers, Liddle (46) found that a lecture-demonstration treatment produced greater positive changes in attitude than did an auto-instructional treatment. Again, it would have been a useful addition to the study if the investigator had discovered whether certain kinds of students make greater changes under one condition than the other. In a similar study where the content was biology, Snitgen (76) contrasted the effects on attitudes toward science resulting from lecture and auto-tutorial treatments and found no difference that could be attributed to treatment. In fact, the attitudes of students who took the course did not differ at the end from the controls who were taking a course in mathematics. The investigator suggests that everybody began with positive attitudes and nothing was done to diminish them. Whey should Liddle and Snitgen, who both worked at Michigan State apparently in the same period, get such different results from what appeared to be parallel procedures?

J. P. Riley (68) wondered how science process training would influence student teacher scores on measures of process, understanding science, and attitudes toward science, science teaching and inquiry strategies. He allowed one group to manipulate materials. A vicarious process training group learned processes through an inquiry strategy that did not involve them in direct manipulation of materials. The control group spent approximately the same amount of time on what Riley called neutral materials. Teachers in both process groups did better than the controls on three of the five process sub-tests: inferring, classifying, and using space/time relations. Students with a previous history of better science grades achieved higher scores on the process measure. There was no impact of process training on measures of attitudes or understanding science.

Barman (11) had a values clarification sequence of instruction inserted into a BSCS Yellow Version biology program. (The control group received standard Yellow Version biology.) He wanted to find out if this addition to BSCS would change student attitudes toward science and what effect it would have on achievement. He measured attitudes with the Schwirian Science Support Scale Form A and feelings with the Affective Domain Measuring Scale. Form J of the BSCS final examination served as the achievement measure. In a pre-post design Barman found that there was a significant positive difference in achievement but not in attitudes.

Bratt (15) described the development and use of an instrument meant to measure intellectual and humanistic aspects of attitudes towards science teaching. The instrument was validated by a factor analytic technique. Its reliability was reported to be 0.87. In contrast to studies described earlier, Bratt found that a group instructed under a humanistic model developed more positive attitudes toward science teaching than did a group instructed in what he called a traditional manner.

Bollen (14) described the construction of a scale meant to assess attitudes of preservice students toward discovery teaching in science. He reported that scores on the measure changed as a result of training in which preservice teachers worked with children in classrooms.

Moore (56) has added to the number of teacher attitude measures that relate to elementary school science. Moore's instrument has six scales, each of which has a statement of the attitude to be assessed, and five sub-statements, each with an agree-disagree scale. The instrument was used in conjunction with a SCIS summer training course. In a test-retest design he found no significant gains for a no treatment condition but, after exposure to SCIS, gains were substantial. Moore interpreted these results as evidence for the construct validity of the scales.

In general, this writer would like to see less proliferation of instruments and more use of the same measures in a variety of studies. As we have already seen, the disparate results of attitude studies leaves us with little basis for understanding and comparison of results. One reason research in education, and specifically in science education, so often fails to give us the kind of guidance we need to make decisions is the lack of replication studies. We do not know enough about the specific limitations of variables or for what kinds of students certain treatments are especially helpful or wasteful.

At best, the relationship between attitudes and knowledge of content is tenuous. The connection is even more tenuous between attitudes and the way people teach. Why should this be? The judges say that caring and enthusiasm for the subject and the student is important. Possibly, what we are facing here is a failure to properly conceptualize what is involved in an attitude. What accounts for its stability? Why is it so difficult to culture new ones? Presumably, an attitude has cognitive content which has attached emotional valence. The strength of the feeling helps to maintain the content of the attitude. To initiate a new attitude is probably not the same as to alter an old one. To culture a new attitude one must somehow provide a milieu potentially rich in feelings as well as the ideas central to the attitude. There are, of course, psychometric consequences of this conceptualization that go beyond simple agree-disagree scales which characterize so many science attitude inventories. In 1935 Gordon Allport (3) remarked that "attitudes today are measured more successfully than they are defined." The statement is still true forty years later! If attitudes have a strong feeling component (i.e., are ideas attached to strong feelings) and if they have some of the characteristics of habits, then it may be pointless to spend time finding out what they are - many people never had experiences in science sufficient to develop genuine attitudes. Relatively speaking, exposure to science may be for most people a null event.

COMMENTS

Much of the research discussed in this chapter seems to be based on the tacit assumption that all students learn in the same way and that all will respond in like fashion to particular educational conditions. Moreover, too few investigators seemed to recognize that their interventions are being made in an interactive, dynamic system rather than an acquiescent static system. We need more studies that examine longer range effects of various kinds of interventions such as changes in levels of structure, questioning, rewarding, pausing, availability of experimental materials, etc. What is more, we need to examine whether some treatments are selectively helpful to some students and are neutral or possibly even harmful to others. Multiple regression techniques may be useful for trait-treatment studies but they are not helpful if one wants to detect time-based changes.

With the availability of computers and multivariate techniques researchers can begin to examine the impact that patterns of variables have on various kinds of outcomes. For example, there are probably interactions among levels of questions, rewards, and pausing. The relationships among these variables need to be examined. Presumably optimal patterns would emerge as a function of goals, type of student and conditions of content. One way to proceed would be to simulate on a computer some possible relationships among variables and then follow this work with appropriate experimental studies. As we come to know more about how the variables are related we can do more to help teachers know how and when to produce particular kinds of patterns. Of course, given that we do find patterns, we would then face a problem similar to the one researchers on biofeedback are presently confronting. They are now trying to teach their subjects to alter the functioning of more than one system at a time. In short, they are trying to teach a pattern of change.

From the research reviewed, what can we say about teacher education in the sciences? How much that people learn in micro-teaching ever reaches the classroom and survives? Surprisingly little. Some does. If the micro-teaching is done with pupils and if in the intern situation the supervising teacher also exhibits the desired behaviors, the changes of success are better. It was suggested earlier in this chapter that if the classroom is an interactive system, then what we need to do is to help teachers learn to "read" the classroom. This means finding ways to help prospective teachers learn to collect and interpret feedback from students.

The problem that faces teachers who have received skill training of one kind or another is to know in what patterns and in what circumstances to put these skills to use. The Jungwirth and Dreyfus (38) study is a case in point. They show that there are four content and process levels of listening that a teacher can learn to recognize and which could serve as a guide for responding.

If we wish to achieve some substantial changes in the way people actually teach, then expose them to a new program (curriculum) and include training in the teaching techniques that seem especially suitable to that program. In short, teaching technology learned in conjunction with new subject matter content and program philosophy gives the greatest probability of change among experienced teachers. Preservice teachers who learn a new curriculum and at the same time learn how that program is meant to be taught are more likely to maintain the style of inquiry in the first year of regular teaching. The most effective ways to transmit the style appropriate to a program seem at the moment to include exposure to models, through films or classroom observation, micro-teaching with children, discussions with peers, and the use of desirable techniques by the supervising teacher.

Research on attitudes and personality variables in science education has not been particularly productive. There is some suggestion that students who learn the most from micro-teaching with pupils are those who are more dogmatic. Less dogmatic students need less practice (21, 26). There is little indication that any constellation of attitudes toward science can be related to effective instruction in science. The failure of attitude studies to produce helpful information may arise from failure to adequately define attitudes and to state how attitudes relate to behavior. Findings from the Myers-Briggs Type Indicator suggest this may be a personality inventory that could shed light on some learning and instructional problems.

Certain teaching techniques appear to nurture student inquiry and more oral language. When teachers regulate their pausing behavior, the variety of questions asked, and their I/D ratios (Flanders), the quantity and quality of student participation improves.

Some studies on questioning report that if teachers ask more higher level questions student achievement improves. However, findings of the relation between achievement and questions were attacked by Winne on methodological grounds.

The Jungwirth and Dreyfus (38) research suggests that high school subject matter specialists be given training on how to hear and interpret what they hear. The best way to give this training is yet to be discovered.

Substantial changes in oral language output, expressed logic, etc., seem to result when teachers increase the amount of time they wait for a reply after they ask a question and the time they wait after a student replies, provided the question is one which calls for more than simple recall. There still needs to be developed, however, a more effective set of procedures for training people to achieve the mean threshold wait time of three seconds.

Sometimes college science educators think teachers need to change but the view is often not held by the teachers themselves. In a study of science teachers' perceptions of their teaching skills, Lawrenz (45) reported that both junior high and senior high school teachers in his sample reported their knowledge and ability as satisfactory to good on all items. If people are satisfied, from where will the motivation to try new ways come?

This chapter began with a question: What is quality in teaching? Do we know anything more about quality now than we did at the beginning of this chapter? Only that the question is complex. Apart from particular people and particular situations to which we can point, we cannot say what it is. Caring is part of it - but how do we measure that, to say nothing of teaching people to have it if they do not? What is excellence? What drives some teachers and students to strive for it while others could care less? Robert Cole shows us in Children of Crises (23) that some children refuse to be thwarted by adversity while others go under. Is the potential for quality, excellence, caring something that develops early and only takes a particular form much later? If that were so, what would it mean for recruitment and education of teachers?

Since the teacher has been the locus of discussion in this chapter, the centrality of the student in the quality of the educational process has been neglected. Good students can make teachers look good. Bad students can make teachers look bad. What is a student of quality? If we cannot achieve a satisfactory answer to that question at least we can look into what effects on the quality of inquiry in science would result if we tried to teach students some of the things we try to have their instructors learn: (a) how to ask productive questions; (b) how to stop and listen to others; (c) how to tell the teacher where they are in the development of an experiment or an idea.

We need to take a more ecological view of research in science education. That calls for studies of longer duration. It implies that we examine multiple relationships as they change their values over time. The ecological view dictates that we find ways to produce a coherent flow of studies designed to build theory. It also means that we encourage more replications so that we can better understand the strengths, limitations and special circumstances which alter the effects of variables. New statistical procedures that allow us to analyze dynamic systems exist. These include path analyses, time series procedures, Bayesian forecasting techniques. More will have to be developed.

In research in science education we are in a state that Newton once decried, we have to explain too much by conjecture. He said it was better to explain a few things with certainty. Perhaps we had better leave questions of quality for the time being to go in search of a few things we can explain with some certainty. We may now have reached a period where some syntheses can begin. If we compound a set of minitheories with good empirical bases we might one day see both the trees and the forest. It may be as Gwen Frostic (30) put it in her beautiful little volume, Wing borne:

> Out in the woods among tall trees
> where flowers blossom and birds build nests
> ---there are no contradictions

She goes on to speak of the tremendous changes and interdependences in the forest:

> This is life --- in all its forms
> so simple
> so wondrous
> so everlasting
> There is no time for inconsistency---
> eternal life is being served (30).

Variety, flexibility, uniqueness are marks of the classroom. The same could be said of the waves that break on the sand, or the leaves that fall from a tree, or the clouds that cross our skies. Underneath the uniqueness of each, however, is a concept. We must go in pursuit of the concepts. Perhaps that is the path to quality.

Finally, the researchers among us must find ways to help practitioners learn about the research results which are relevant to them. Researchers had better improve their ability to communicate effectively!

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CHAPTER 7

SCIENCE, SOCIETY, AND EDUCATION AT THE CROSSROADS:

ON LEARNING HOW TO MAKE LOVE IN A LIFERAFT

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In my most rational moments, the notion of thinking of science education in the future in any terms other than those of the past seems ludicrous. My understanding of science teaching in the United States as it has been practiced over at least the past hundred years suggests a fairly monolithic, unvarying approach to our job: dominance by textbooks, teachers, and a single cultural philosophy of what schools are all about.[1] I can see a future for science education which is likely to incorporate more recent information from the sciences and which, reacting to the social crisis of the moment, adopts quirks in the standard curriculum for relatively brief periods of time. I can envision teachers making more frequent and, perhaps, more intelligent use of the technology which is even now available to them. But in these moments of rationality, I somehow can't imagine the schools of 2076 being fundamentally different from what they are today.

I do have flashes of optimism from time to time, however. They come when I focus on what might be and when I am able to forget all those factors that mitigate against change within our society and within education. In these dreams of hope, I see a vastly different kind of science education from what we have had in the past . . . and probably from what we even talk about today. These dreams are based on a lingering belief that we really may be able to recognize not only that there are significantly different ways of helping people to learn, but, far more important, that we will find the will and the way to implement our finest visions. In the hope that talking about those visions will increase the probability of their occurring, I write this chapter.

Whatever optimism I feel for the future of science education (and for our society) arises out of what I understand to be the unique experience of cultural transformation which we now seem to be observing. Some observers are suggesting that human societies are going through a period of change which may be quite unlike that since the development of agriculture thousands of years ago.[2] To the extent that this is true, there is more hope that the basic, significant, even radical changes that I believe are necessary in our social institutions and cultural mores may come about.

My intention in this chapter is to examine briefly some of the important (to science educators, at least) elements which seem to be involved in the current watershed of our cultural history, the contribution which each has made to the present (1976) state of affairs, and the way in which each might be involved in some alternative view of science education in the future. The three elements to which I refer particularly are (1) the nature of modern science, (2) the characteristics of the social/economic (and, to some extent,/psychological) system in which we live, and (3) the intentions which motivate our system of formal education.[3]

> Science was once the noblest flower of the human mind, and the most promising source of material benefactions . . . there could be no doubt that its practical activities were the main basis of Progress. Now we have a very different picture. The troubles of our times seem themselves to be a consequence of that very progress (1).

No group of science educators has to be told about or convinced of the remarkable achievements of modern science. If we speak of science in its purest sense, as a system of thought, there probably has never been so reliable a process developed for arriving at "true" statements about the natural world. And if we test science by examining the practical fruits of its labors--its technology--we are overwhelmed by the impressive array of its achievements. By either standard, science has succeeded beyond the wildest dreams and predictions of Bacon, Galileo, and Newton.

The successes of science result, as we constantly remind our students, from a unique set of assumptions, methods, and rules to which scientists subscribe and by which they work. The scientific mentality includes a number of elements familiar to us all: eschewing teleologic for purely descriptive explanations; dealing solely with material objects and with phenomena that have material manifestations (and yet abstracting and idealizing from specific cases to general principles); expressing observations, interpretations, and explanations quantitatively rather than qualitatively; making all information (data and interpretations) available to all other workers in the field, relying thereby on validation by confirmation from competent colleagues; maintaining distance between scientific issues and political, economic, social or personal considerations; and so on.[4] Along with these--which seem to me to be essential rules about the way science is done--are a number of less firm, generally unspoken, sometimes questioned by-laws which also dictate what scientists do in their professional work and how they do it: anything which can be done, will be; if you you don't do it, someone else will; to the victor (discoverer) belongs the spoils (the Nobel Prize); science is amoral, and what happens to its discoveries and inventions is beyond the control of scientists, and so on.[5]

Lay persons and some scientists are inclined to pad this list with certain additonal elements which, although admirable, are not the special province of the scientist. Most scientists, for example, are probably no more basically honest or free from corruption than the average lay person. There is not much reason to believe that they are any more motivated by humane intentions or the spirit of brotherhood than are lawyers, merchants or Indian chiefs. We make this point not to degrade scientists, but to further strengthen the case for the internal integrity of science. If scientists seem more honest, the reason is likely to be that they know they'll get caught if they cheat!

The mechanisms by which science operates assure that "truth will out" eventually, so that dishonesty is viewed by scientists not simply as immoral but, more practically, as inevitably unproductive. The intellectual engine that is science does, indeed, have a self-correcting mechanism that protects its "truths" against corruption by the misinformed, the incompetent, and the dishonest who may be found within the profession.

What we all need to understand better about the way science is done, I believe, is that these rules, understandings, and assumptions among scientists guarantee that scientific knowledge will develop and be confirmed in isolation from the political, economic, social, and ethnical realities of the everyday world.[6] For the mechanisms of scientific discovery which have produced a myraid of true statements about the natural world do not include techniques for valuing--assessing, limiting, or controlling--those statements. Science, as we have all been taught, is amoral. There is nothing good or bad about a "true statement" in science. It just is.

Scientists may--and do--argue that since this is true, since these are the rules under which scientific research is done, they are not responsible for what happens to the fruits of scientific progress. Whether that be so or not, the fact is that scientific developments have almost always had a variety of social and (often) philosophical implications. For most of the history of science, to be sure, the "true statements" of science have probably had an overall beneficial effect on humankind. I'm aware of the use of scientific principles, from Archimedes to Ford, to increase the efficiency of human destruction through scientific knowledge. But, all in all, the benefits of scientific progress seem to me to have outweighed their harmful effects. Under such circumstances, the question of "controlling" scientific discoveries would seem to be essentially moot . . . as it generally has been.

But, "the times, they are a-changing." The question I raise is whether the nature of scientific discoveries now being made and likely to be made in the near future are essentially like those of the past or qualitatively different and possibly unique in human history. My feeling is that the frontiers on which scientific research is now going forward are, in many cases, in the latter category. If that be so, scientific progress from this point on may pose moral and social questions which were academic in the past but which now are both practical and urgent. Consider, for example, the somewhat fantastic case study which follows:[7]

Imagine an organic chemist who has synthesized a new compound that makes possible instant interspatial transport of humans. One takes the compound, thinks himself/herself to another geographic location, and instantly appears there. After seven years of research, there appear to be few serious side effects (the "loss" of about one subject in 80,000), and commercial interests are eager to learn more about the discovery and get "the pill" into production.

The question I raise here is what responsibility the inventor of this compound has, beyond the normal professional responsibilities (reporting his/her results, for example) to deal with the social, political, economic, and ethical consequences of this discovery.

Probably the most important point to be made about this example is that the mechanisms of science itself provide almost no answer to this question. The chemist's first responsibility is to disseminate his/her findings to others in the field for their own study and eventual confirmation or disproof. This might be done in a conference paper, a journal publication, or a personal communication. But theoretically at least, the news of the discovery would shortly be making the rounds of laboratories around the world, where chemistists of similar interest are working.

For those of us who see only benefits resulting from this discovery--instant solution of the world's transportation problems, for instance--there is no reason to question the steps which would normally follow such a discovery: publication, confirmation, and (probably) commercial production. But for those who see possible harmful effects--massive unemployment as General Motors, Ford, Chrysler and American Motors go out of business, for example--questions may arise. Would we be willing to make such a discovery available to anyone (including researchers in the Soviet Union, the U. S. Department of Defense, and Dow Chemical Company) without any control?

The interesting and troublesome point is those who are concerned about the possible misuses of scientific inventions have almost no completely adequate recourse available to them. One can, of course, hope for and appeal to the moral and social consciences of individual scientists. But this tack has almost never had any real effect on the dissemination of scientific discoveries.[8] Besides, the idea of protecting new information is inimical to the basic tenets of openness which have made scientific progress possible. Throughout history, then, the simple fact has almost inevitably been that scientists do release their discoveries to their colleagues, and the responsibility for their ultimate use is laid at someone else's door.[9]

We could, as an alternative, ask governmental agencies to act as watchdogs over scientific developments, but this is an awkward suggestion to make in the United States in 1976 when confidence in public officials is not very high. Besides, some argue that the military (at least) already over-protect certain scientific information and that other governmental agencies charged with supervising and overseeing the fruits of scientific research have been less than spectacular successes.[10]

The aspect of modern science which seems to add a new dimension to this (formerly academic) question is quite simply the potential of modern scientific discoveries. Perhaps fusion and fission bombs are really not all that much different from traditional chemical explosives. Perhaps the threat of chemical and biological warfare are really nothing new in human history. Perhaps the new techniques of fetal surgery and genetic manipulation are just an extension of previous research and nothing to be overly concerned about. For my own part, however, I doubt that any of these is a fair view of the true significance of the issues arising out of much current scientific research and technological development.

My own impression is that the manipulative techniques now being developed, particularly in areas such as genetic surgery, behavior modification, psychosurgery, organ transplants, electronic surveillance, definitions of mental illness, and the like, have taken us across a new threshhold in terms of the ethical challenges which confront both scientists and non-scientists. It is the nature of current discoveries and the directions of current research that incline me to the view that the traditional _laissez_ _faire_ approach of scientists to the ultimate employment of their discoveries and inventions will not be adequate to the world of the future.[11]

> It's disgusting to have to listen to all this talk about morality. We're here for dividends. If the B-1 bomber's gonna make money, that's good enough for me (7).

Perhaps my concern about the uses of scientific developments would be less had I a better feeling for the culture in which we live. If love, beauty, kindness, and respect for life were the guiding principles of our way of life, we could truly look forward, with Bacon, to the arrival of the new Atlantis. But there seems to be previous little reason to hope that, whatever direction we move in the future, it will be motivated by concern for the greatest good for the greatest number.

It is difficult for me to hope, in the first place, that we can look for wise and humane use of scientific research by the _private_ sector of our economy (as our society is often called). Ours is still very much a capitalistic state in which _profit_ is the motive force behind business and industry. General Motors, Westinghouse, Hood Dairy, and the AMA are, after all, not primarily in the business of making us all healthier, happier humans, or looking for ways in which they can protect and enhance the environment. If human betterment and profit are compatible, so much the better of course. But the two do not necessarily go hand in hand, and I think we now have abundant evidence that human welfare must often take a back seat to profit-making. Thus a social order has developed in which making a profit is the touchstone of success--making it necessary to clog the countryside with quickly obsolescent automobiles that putrify our air, to use food preservatives whose long-term effects on human health are sometimes uncertain at best, to provide elaborate and expensive medical care for the very wealthy at the cost of almost none at all for the very poor, and so on and on and on, and we recognize with horror that we live by social and economic rules which too often elevate the value of real property over that of human life!

At least since the time of the Industrial Revolution, businessmen have recognized the potential value of technology to their operations. The last thirty years, more particularly, have seen a vastly expanded role for scientific and technological development in the maintenance of business, industrial, and corporate profits and, by extension, the American economy.[12] A group of science educators hardly needs to be lectured about the pervasive influence of science and technology in our daily lives. All of us have spoken to our students about television sets, antibiotics, computers, transistor radios, food additives, genetic surgery, "smart" bombs, and electronic surveillance in police states, emphasizing their need to understand this important aspect of their lives. Whatever it is that scientists and technologists are able to discover and invent, it will almost certainly be put to production and use by *someone* in order to make a profit.

Within this ethic, it is hardly surprising that abuses of scientific discoveries occur. DES is used to fatten cattle more rapidly, thereby insuring greater profits for cattlemen (and increasing the probability of some kinds of cancer); chemical fertilizers are used in ever-increasing quantities to maintain and improve crop yields and profit margins for farmers (destroying in some cases the soil's natural fertility); electronic manufacturers aggressively peddle television cameras that can be trained secretly on students during their noontime breaks or in the lavatories, to make sure that drugs are not being used (teaching them thereby the hypocrisy of those who preach about rights of personal privacy and individual freedoms); large numbers of boys and girls become the market for a wide array of prescription drugs aimed at curing their hyperkinesis (demonstrating to us all that scientific and technological fixes are really easier, safer, and more profitable than attempts to understand aberrant human behavior); and so on and on. As in our dealings with nature, it seems that for every benefit we gain, there is a significant price we must pay.

I don't mean to suggest by the preceding that business and industry in this country are playing any great con game with us, that they seriously expect us to believe that their primary aim is or ever has been the betterment of humankind. We have been quite consciously taught that profit-at-(almost)-any-cost is the *raison d'etre* of business, of capitalism, and of corporate society. It is "The American Way," the Puritan Ethic which has made this country great. What we *have* been taught--and now take as a matter of faith, I believe--is that in those cases where business, industry, the unions, or other organized groups get carried away with their own interests (whether they be profit-making, power-building, or whatever), private citizens can expect protection through our elected representatives in local, state, and national government.

Thus, it is to *government* that we look as the natural and reasonable place for protection against abuses and excesses by organized powers against individual citizens. If science *can* not monitor the fruits of its research, and if industry *will* not, then it is left to government to speak for the public interests in the utilization of scientific and technological developments.

This is certainly a part of the rationale behind the establishment of federal regulatory agencies. Decades before science and technology became a major influence in American society, agencies such as the Food and Drug Administration (dating as early as 1907), the National Bureau of Standards (1901), and the Commodity Exchange Authority (1922) were established specifically to serve as watchdogs of the public interest in a wide variety of areas. The well-documented failure of these agencies of the federal government to protect much of anything beyond the business and industrial interests which they are supposed to regulate is by now well known.[13]

(We can't begin to comment here on the implications of the widespread disillusionment and disenchantment with governmental agencies--at a time when we are perhaps beginning to need them most--arising during the past decade. The long-term significance of these feelings is, I believe, enormously important in the context of the science/society issues raised here.)

> Our most urgent problem . . . involves educating people to an understanding of the nature of power so that they can be persuaded to struggle against it . . . The principle obstacle to an understanding of power is the intensity of the desire to possess it (6).

My discussions so far have focused on the evils of corporate capitalism and profit-making in the indiscriminant use and misuse of scientific and technological developments. I believe that on a superficial and easily-demonstrated level, this has probably been a fair description. I suspect also, however, that there is a far deeper, more basic, and more pervasive force shaping our society than simply the desire to accumulate wealth. For what, after all, is really so inherently immoral about the quest for profit? Indeed, we are often told that the profit motive is the cornerstone of our way of life, the engine by which a better way of life is provided for all of us, and, sometimes, even a manifestation of our devotion to certain religious ideals.

If the accumulation of material goods were, in fact, to lead to a safer, healthier, more comfortable life for all people, one could hardly argue with the corporate quest for profit. It is not hard to demonstrate, however, that the aim of profit-making is to maximize the material income of a very small fraction of the population at the expense of the rest of the population. Philanthropic foundations established by the Carnegies, the Mellons, and the Rockefellers of this nation were not created primarily in order to provide a comfortable living for those families and then to distribute the rest of their great fortunes to the poor of the world, but to provide tax shelters which protect these enormous fortunes. Neither is the reason behind Exxon's efforts to find new oil, to buy up potential coal fields, and to develop new energy sources (at taxpayer expense) to provide better living for us all, but to add to the personal fortunes of a small number of already very rich families. No, the motive force behind profit-making is quite simply and directly the accumulation of power, power over the possessions and the lives of others, often at the cost of the possessions and the lives of others.

We live in a culture, I say, defined by power relationships: Governments exert power over our individual lives by legislating what we may or may not do in our bedrooms, what we shall or shall not see on television, whether we shall or shall not even have the opportunity to eat. Business and industry exert power over us by determining how we shall or shall not travel from one place to another; whether we shall or shall not be able to purchase healthful foods, whether there shall or shall not even be a marketplace in which to buy. Schools exert power over students by passing judgment on their social and economic backgrounds, their peculiarities of language and their class or personal moralities, by determining who shall or shall not move upward in the educational ladder (not uncommonly on totally irrelevant intellectual criteria), by demanding of students a portion of their own personhood as the price of certification for social respectability. Men exert power over women by withholding from them economic equality, by exercising sexual priority and control over their bodies, and by denying them the basic dignity and respect which they share with each other.

Definitions of success in our culture have their locus in successful power struggles: the boasting of a teenage man's conquests of women; the attainment by the professional scientist or science educator of an award or a better position; the ability of an oil company to show enormously increased profits in the midst of a fuel shortage; the attainment of peace with honor in a nation raped and devastated by the American military machine. It probably does not miss the mark too much to say that for most of us, our very definitions as persons are functions of our relative positions in various power relationships.

And what has science to do with a culture so thoroughly embroiled in power struggles? The connection is neither tenuous nor obscure. Lynn White[14] has put forward the proposition that science (the attempt to win control over nature) developed in Western civilization first because it was more compatible with a traditional Judaeo-Christian philosophy of "go forth and conquer the earth" than it was with an Asiatic cultural view of finding peace within oneself. In any case, it seems obvious that those who delight in the struggle for power--those who would do battle with the environment and with their fellow humans for the fruits of success--will find ready allies, both philosophically and logistically, with those who labor in science and technology. Scientists who have argued that "knowledge is power" can hardly be surprised today to see the merchants of power in our own society employing the fruits of technology in their daily wars: synthetic fertilizers and pesticides in more successful agribusiness; behavior modification techniques for more efficient education; electronic hardware for the improvement of government and industrial snooping; and so on.

Perhaps confrontation, conflict, and struggles for power were natural or necessary in a world of want. But the United States of 1976 is not Third Century Rome or Sixteenth Century England or even the United States of the 1920's. Science has shown us how to conquer the ghost of starvation and perhaps the time has come to reassess a set of cultural values based on a view of human's place in the natural world that no longer exists.

I go on at some length about the dangers of a society defined by power relationships in the modern world--a topic which I am only now beginning to understand in a vague and incomplete way--because I do not believe that attacking superficial issues (i.e., economic systems) will help our culture to find new meanings and new directions. I believe socialism and communism and anarchy can be as evil and mean as can be capitalism. I am convinced that a meaningful analysis of the future in a post-scarcity, post-technological society _must_ involve a better understanding of the origin, nature, and significance of power relationships in our culture. I say this now, and I return to the point later because I am convinced that power corrupts, and, in our society today, increased power is producing increased corruption in a very pervasive and essential sense.

> School is where you let the dying society put its trip on you. Our schools . . . exploit and enslave students; they petrify society; they make democracy unlikely . . . it's not what you're taught that does the harm but _how_ you're taught (3).

So what do schools have to do with all this? It is almost axiomatic that schools are the agents of society. Formal education, wherever and however it exists, is designed not only to give people necessary work skills, but also to socialize them to the mores, customs, beliefs, and social patterns of their own culture. It would be surprising in the extreme if American schools departed from this traditional function of education, and there is scant reason to believe that they have to any considerable extent.

This point, though perhaps obvious, is important because it draws our attention once more to the _essential_ role of schools in this society and to the extent to which they are successful in filling that role. Within this context, our _traditional_ arguments as to what schools are about are incomplete at best and a sham and camouflage at worst.

The aim of American schools, then, is to develop the kind of citizens who fit into our way of life. This means in 1976, first of all, men and women who can fit into the various vocational slots that need to be filled in a corporate society: assembly-line workers, managers, compliant and eager consumers (i.e., husbands and housewives), for example. A large number of these jobs require, more than anything else, an appreciation of work that has a new meaning in human history: work that, _per se_, has no meaning. Millions of Americans spend their working lives shuffling papers, bolting on fenders, standing in line to collect welfare payments, passing on trivial information to bored students, and doing any number of other tasks whose beginning, end, and eventual significance they will never see and perhaps never understand. A society based on so much meaningless work can be stable only if its workers are trained to tolerate--even to value--boredom, ambiguity, and meaninglessness.

Similar virtues are necessary to survive in our nonworking lives. The success of commercial television, American-style consumerism and even national politics demands the suspension of rationality and intelligence and the development of a compliant, dull, unimaginative, and unquestioning outlook on life. From the highest level of our society ("We must trust the President to do what's right; he knows more than we do.") to almost the lowest ("Use Smiley toothpaste and be the most popular girl in your neighborhood."), ours is not to question why, but just to do and die in the cause of the American economy.

If this argument is true, it explains some of the absurdities of American schools, for example: a curriculum so remote from reality that it never has meaning to most students, so that those who succeed in it are, more than anything else, experts in surviving meaninglessness . . . a compulsion in schools with rules: the same rules on which, not so coincidentally, successful business thrives (good grooming, punctuality, efficiency in handling forms, respect for authority, etc.), but which have only a marginal relation to the act of learning . . . emphasis on competition and power struggles: education becomes a contest in which there are always winners and losers (the curve) and in which the stakes eventually become each student's future life.[15]

The energy with which teachers can argue the virtues of chemistry course "A" versus chemistry courses "B" often amazes me. The basic question is what chemistry (as we teach it) is doing in the curriculum at all! The natural outcome of the "A" versus "B" debate is that it drains off teachers' energies into irrelevant areas and away from the really crucial questions of education. As long as we continue to analyze schools exclusively in terms of their supposed intellectual functions (teaching a mastery of chemistry, biology and physics, for example), I doubt that we shall achieve reform that has much meaning. When we recognize that schools are primarily sorting devices and training (i.e., socializing) institutions, we shall have a better perspective from which to improve education.

> Biology is not just another subject to be studied in school. Biology is national defense, biology is our high standard of living, biology is our social and economic welfare, biology is the survival of our democracy (8).

In summary, here is how I see the combination of science, society, and schools as having potentially evil effects on the lives of U. S. citizens in 1976. To begin with, the American (i.e., U. S.) dream is one of the most optimistic, most promising experiments in government ever attempted. It is based on perfectability of humans and, as much, it offers men and women the greatest gift that any society can offer individuals: freedom. We are still very far from having attained that dream, and our history is heavily marred with wars of imperialism, hatred of minorities, abuses of personal rights, and other failings. At this point in history, however, the dream still allows me to speak out and it still holds much of the promise that motivated the events of 1776 and 1787.

The dream continues to elude us and, at times, seems to fade with terrifying ease as threats to the concept of maximum human freedom within a harmonious society are under attack from two directions. The first and more obvious threat is from the simple erosion of democratic government. One lesson of the Nixonian era (if we needed yet another example) is how easily democracy can degenerate into totalitarianism. More than that, how effectively and easily science and technology can become the (either willing or unobjecting) handmaiden of that totalitarianism (computer files on citizens, plans for implanting transponders in criminals' brains, Vietnam-tested riot control techniques for use by domestic law enforcement agencies, and so on). It may be unfair, unrealistic or simply just too early to compare the United States in 1976, but the Brave New World, the Oceania of Orwell's 1984, and the Ilium, New York, of Vonnegut's The Player Piano all functioned as effectively as they did largely because advanced science and technology made it possible for them to do so.

The second, and less obvious, threat to our freedom, I believe, is contained in the complexity of the world we live in. There isn't much point in having one's freedom if all important decisions are made remotely in such a web of complexity that one is, for all practical purposes, excluded from those decisions. Consider for a moment the food crisis which demands so much of our attention now. There certainly was once a day when each person had a fairly good idea of where his or her food came from and of what happened to the money he or she paid for it. There often (usually) was not enough food for everyone, but the mechanisms of food transfer were easily understandable. Today, it is all but impossible to trace the patterns by which food is produced, processed, delivered, and sold. Bumper crops in the fields may somehow drive prices up, and high prices in the supermarket can cause cattlemen to slaughter their herds to avoid going bankrupt! No one seems to know how a change in any one part of the food industry is likely to affect any other part. The consumer's freedom to act in the marketplace is reduced essentially to a buy or not buy decision. For almost the first time in human history, we have the ability to produce all the food our people need, and we have no idea how to use that ability to feed hungry men and women in this country. Neither freedom nor rationality have any role in dealing with this essentially irrational process.

I raise this point and offer this example not simply to bemoan the passing of those simple days of yore, but to highlight the absurdity of modern schools in the context of this situation. In the midst of a world filled with complex problems, what are the schools doing? They seem bent on offering the most harmless, most superficial, most useless kind of education, destroying imagination, stifling curiosity, "ignorizing"[16] those who spend their times there, avoiding controversy, developing conformity, and, in general, refusing to help students (and people in general) to understand and to deal with the difficult and complex realities of everyday life. Educators, locked into the antiseptic process of doing as they were done to in their own monodisciplinary way, prattle on about irrelevancies such as simultaneous linear equations, how a bill becomes law, the Krebs cycle, heats of formation, and interference patterns even as they are surrounded by difficult issues crying for imaginative, creative, intelligent interdisciplinary solutions.

> Now, as once before in the disintegrating classic and medieval worlds, the achievement of a new personality, a new attitude toward man and nature and the cosmos, are matters of life and death. We must recapture once more our sense of what it is to be (human): we must fashion a fresh way of life, which will give to every (person) a new value and meaning in . . . daily activities (5).

My analysis of science, society, and the schools thus far might lead one to believe that I see only a rather grim future ahead for our culture. At best, perhaps, continued material comforts accompanied by an increasingly impoverished human spirit. A continued collusion, almost certainly, involving scientific discoveries and inventions, commercial thirst for profit and for power, and governmental alliances with big business interests. A continually complex society in which the notion of human freedom has less and less meaning and in which men and women willingly or grudgingly sacrifice more and more of their independence so as to find stability in their own lives. And, indeed, I have confessed at the outset that I do not view the next few generations in a particularly optimistic light.

Nonetheless, it is obvious to me that a number of alternative futures are possible and that at least some of these hold great promise for our progress as human beings. In the final sections of this chapter, I propose reviewing some glimpses of the future which I think of as encouraging and about which we should learn very much more.

Different attempts to predict the future are likely to have varying degrees of success. Those who view the future as an extrapolation of historical and contemporary circumstances--as do the futurists who work for Disney World, in one sense, and those who work for the Club of Rome, in quite another--might reasonably expect a high degree of precision in describing to us what the world of tomorrow will look like. If basic attitudes, beliefs, and behaviors in our society do not change, it should not be unreasonably difficult to describe the world of 2076.

My own conviction is, however, that this historically reliable way of looking into the future by examining past and present trends is inadequate to the circumstances we face today. From all that I can understand, the cultural revolution through which we are moving in the United States in 1976 is quite different from any previous stage of cultural evolution. Even if that did not seem to be a true reading of what is the case in our contemporary society, I would argue that radical and revolutionary changes are dictated by what we see happening all around us. Much of that which has worked well for human society in the past has now become counter-productive, obsolete, useless, suicidal, dead.

The challenge to those of us living in the United States in 1976, I suggest, is to begin to look for new ways in which we can talk about what it means to be human: a new group of attitudes, a new code of behavior, a new set of social institutions, a new cultural ethic. For most of human history, social relationships have been defined in terms of sexism, racism, classism, conflict, competion, patriarchy, hierarchy, power, fear, hatred, and death. Our opportunity is to find a new definition of humanity which is grounded in new and different terms: equality, toleration, trust, compassion, cooperation, and love. Making use of the unprecedented material advantages which science and technology have given us--the ability to overcome human hunger, to conquer disease and poor health, to supply minimum living comforts with relative ease--we have the opportunity to begin to find out what mental, emotional, and spiritual heights human beings are capable of reaching.

> . . . the task that now confronts American educators . . . is nothing less than the attempt to educate a generation equipped to undertake the formation of the patterns of a new civilization (2).

Obviously, any serious attempts to talk about revolutionizing society are beyond the scope of this brief chapter and my limited competence and understanding. My intention, therefore, is to suggest the priorities I think we could and should adopt, the directions we might choose to follow, and the strategies of change we might develop. Most of what I say will be phrased in terms of the schools and formal education, although I readily admit that most of the changes that should and will come in the next hundred years will probably make the first of these terms obsolete and will drastically redefine the second so as to make it virtually unrecognizable to us.

I choose to talk in terms that I think are much too heavily laden with tradition simply because that is where most of us--writer and readers alike--find ourselves. Whatever hope we have for the future, whatever contributions we may be able to make toward changing society, will take place within the context of our workplaces: the schools and the colleges.

This statement reflects a somewhat different view of the role of schools than I have admitted previously: that of change-agent in society. In some respects, assigning such a role to schools might well be the most revolutionary recommendation I could make. For although we sometimes speak of formal education as a means of bringing about social change, that view is probably unrealistic and not correct historically. Formal education in almost any society is designed to acculturate the young to social values and customs before they become old enough to resist it as effectively as they could later.[17]

Education in the United States is no different. It probably never has been, is not now, and never could be other than a process of socialization. No, I'm not suggesting that teachers lead their students into the streets to bring about the violent overthrow of the very society that spawned the schools when I talk about revolution. I am suggesting that formal education (the schools) may best be able to serve our society by examining the values and institutions on which our culture is based by searching for alternative attitudes and behaviors by which we might live, and by helping people develop the knowledge, skills, and self-confidence to continue a thoughtful reassessment of the potential and meaning of culture change throughout their lives. It simply will not do--it just won't make enough difference--if science teachers and science educators continue to talk about ways of doing better the things they are now doing or to find better things to do within the present overall structure of formal education. If we are serious about making significant changes in education, we must look beyond the reform of curriculum to questions of educational bureaucracies, the politics of education, and the very role and function of education in our society.

How does all of this translate into things that we do in our classrooms, our schools, our college, our offices, or wherever we have chosen to do education? Some beautiful, optimistic, and encouraging visions of what we might have and of what we could do have already been written.[18] The common theme that I have read into so many of these works has been a principle that I think we need to take as a guideline for all future actions, namely that we care about people (in the singular at least as much as in the collective).

Such a statement may seem trite and trivial; I claim that it is a revolutionary stand. To be sure, we have always argued that schools in the United States are concerned about students, that we have their best interests at heart. It seems to me, however, that any objective analysis of the way schools in this country have worked simply would not support that argument. Every indication I have is that schools operate primarily for the convenience of and to satisfy the demands of industry, business, custodians, labor unions, parents, colleges, teachers, or society in general, but almost never for the benefit of students themselves. Some years ago, Earl Kelley wrote,

> . . . we do not like youth very well . . . They (our schools) are not warm and friendly to all kinds of youth. They repel the very ones who need them most . . . They are too much in the grip of the dead hand of the past, while youth are naturally looking ahead to decades their elders scarcely dream of.[19]

I think that statement was a fair one then and is still a fair one today. The question is really not whether teachers love their students (I think in general they do), but whether the structure of education allows us to do other than to judge, manipulate and sometimes, unhappily, to end up hating those whom we hope to teach.

I suspect that when we have talked about the needs of students, it has almost always been in the context of how to fit them into society with the least amount of friction. Seldom have educators been concerned with developing those personal traits--literary, musical, or artistic talent; craft and handiwork skills; self-understanding, curiosity, and imagination; skills of social criticism; physical and sensual development--which might be personally fulfilling or which might lead to any social behavior other than maintenance of the status quo.[20]

Should we apply the principle that we care about people to schools as we know them, we might expect to be confronted by a number of significant new questions. Here are just a few that occur to me:

What is it that teen-agers most need to know about science? An understanding of the physical physiological, anatomical, and biochemical changes going on in their own bodies, perhaps. Or a way to assess and deal with the sex roles they are and have been assigned and are developing. Or the knowledge, skills, and opportunity to do something worthwhile from which they can develop self-confidence and self-esteem. Or the ability and skills to analyze, assess, and act on consumer information they see and hear in advertisements every day. I can easily understand why and how one might want to reform the present-day science curriculum in order to introduce more courses in sex education, the social implications of science, bioethics, career education, consumer education, drug education, and the like. All of these have the potential of making one's educational experience more realistic, more useful, more liberating.

Indeed, to whatever extent there is validity in my concerns about the misuse of science in our society, it becomes essential that we teach about science in such a way that they are not simply awed by it, but are able to understand how it works as a social institution, how its products are put to use by business, industry, and the government, what hidden biases there are in scientific research, and so on.

But in what sense do adolescents need to know atomic theory, the gas laws, wave motion, characteristics of the electromagnetic spectrum, the Krebs cycle or the hundreds of other topics which make up the traditional biology/chemistry/physics core of our science education program? Only in that these are the abstract, formal, intellectual hurdles we have decreed that students must jump successfully in the junior high school in order that they may pass to the senior high school in order that they may go on to college in order that they may be graduated. They are--except for those whose careers are in science or science-related field--almost all form and no substance. They are virtually perfect examples of the school's insistence that its graduates be able to do irrelevant, senseless, trivial things--and do them well--in order to receive education's mark of approval.

The very first mission of science educators, therefore,--as trivial and insufficient as it may be in itself--is to reform curriculum, replacing our hundred-year old and obsolete dependence on abstract, academic science with studies that have meaning and significance to those in our charge. As limited as this step may be, I recognize the difficulty in moving even this far. College teacher education programs have almost nothing to say about human sexuality, about gender role development, about politics and science, about bioethics, about drug education, or about any other issue of real significance to youth (or adults). Trapped on the same old merry-go-round of academic travia as the schools, we provide our future teachers with none of the understandings, knowledges, skills or attitudes they will need to become change agents in even the simplest and most trivial respects. At a very minimum, teacher educators must stop spending their time and effort in helping future teachers do more effectively those things which they probably ought not to be doing at all! Schools and the teachers we supply to them can never become change-agents unless colleges and those of us who work in them begin to understand and practice change ourselves.

I do not mean to imply that I think curriculum reform is a sufficient objective in itself. Indeed, I think it is little more than a first step. Schools oppress students not primarily by what they teach, but by how they are organized and how they operate. The organization of education in mini-factories undoubtedly developed for good reasons and unquestionably functions efficiently from a business standpoint.[21] But there simply is not and never has been any psychological or intellectual justification for organizing learning around groups of about thirty same-age students brought together in discrete rooms built solely for that purpose and utilized in arbitrary blocks of time during a certain part of each weekday for about nine months out of the year under a complex and extensive set of rules, regulations, customs, behaviors, and beliefs which have almost nothing to do with intellectual learning itself.

It is always somewhat incredible to me that most of us who seek educational reform find it difficult to recognize, let alone to question, the basic assumptions which are probably most responsible for whatever problems we now have with education. What special virtues are there, for example, in isolating all (or the vast majority) of formal education in school buildings? Why not make use of art galleries, church buildings, airports, police stations, laundromats, supermarkets, government offices, construction sites, and dozens of other naturally educative locations? Experimental programs like the Parkway Project[22] and dozens of free and experimental schools have provided us with models of at least the first steps in organizing learning (if, indeed, learning needs to be organized, and, if so, in what sense) in ways other than that of the factory school.

Other basic questions can be raised. What, for example, is the proper time for formal education? Is is something that is reserved almost exclusively for the first fifth, quarter, or third of one's lifetime? Is it something intended primarily for the young and made available only in trivial ways to adults who have nothing better to do with their time? Is it something that is always preparation for and never inherently useful in and of itself? To the extent that formal education is any or all of these, it is divorced from learning, for learning is a normal human activity that goes on at all ages, in all circumstances, for all people. When we admit that formal education is, in our society, restricted to certain (young) persons in only certain settings, we also concede the extent to which it has been isolated from true learning.

If those of us who call ourselves educators truly care about people, we should be concerned that those who need understandings, knowledges, and skills can find these when they need them. As those who have special background in science, we need to have a particular concern that men and women, boys and girls, have every opportunity to understand the intellectual mechanisms on which science and technology depend; to learn what science is like as a social institution;

to know how to evaluate the applications of and to protect oneself against the misuses of science and technology; to find out how to monitor, judge, and control the influence of scientific and technological progress on one's own life. Endless specific examples--certainly not restricted to the adolescent years--are possible:

Citizens of a town faced with the prospect of a new nuclear power plant in the neighborhood; a man or woman of age 53 who becomes unemployed because of new automated machinery; the family faced with an incurably ill child or parent; a society struggling with a new understanding of mental illness; a group of farmers challenged with environmental pollution resulting from their continued use of pesticides and artificial fertilizers; a teen-age boy deciding what gender role model he feels comfortable in . . . in every case, decisions were knowledge, understandings, and skills are needed . . . where learning can, should, and, one way or another, must take place. Schools are not the answers to these real problems of learning, and our continued reliance on schools as the mechanism for assisting learning is simply an admission that we really don't understand what the real educational needs of our society are. At least one other challenge to educators who care, then, is to find and develop new modes of learning for whoever it may be that has needs, wherever those needs arise.

As we raise questions about the forms in which learning can occur, we can hardly avoid asking also what the role of a teacher ought to be. The term has come to be reserved for those of us who have studied four, six, eight, or more years so that we may do unto others what has been done unto us. So specialized has become the field of pedagogy that many of us who teach know much less than we ought about the subjects in which we are expert. Few of us in science education, for example, really know what it's like to be a scientist; to run quality control tests at Upjohn; to make water pollution tests for the EPA; to do basic research in the Bell Labs; or to test new weaponry for the Department of Defense. Why can those who know and understand and do not also teach--at least sometime, to some people, in some places. Perhaps the best person to teach about bioethics is the doctor who daily decides which persons shall live and which shall die . . . or the patient who faces an organ transplant next month. Perhaps the best teacher of auto mechanics is that teen-age boy or girl who failed algebra for the third time last semester. Perhaps we could all learn best about consumer education by working for three months in an advertising agency or a local supermarket warehouse.

Expanding and redefining the meaning of teacher does not suggest to me that we professionals extend and diversify our own job descriptions; it does not suggest to me that we bring in or go out to experts outside our field. It suggests to me that we begin to think of education as an integral part of a rapidly and ever-changing society in which every person learns and daily relearns what it means to be myself, what society is and what it ought to be, where I/we am/are going and how best to get there. The help and guidance one needs in this continuous process of learning probably can be, should be, and almost certainly already is available to us from a dozen different directions in a dozen different ways. We have but to see when and how each of us can and should function as a teacher and when and how each will be a learner.

> Or shall we find a new way, finally change everything, not just the usual categories of politics or economy, but society itself, the dynamic of roles and identity, all the basic structures, the family, sexual identity, the self itself? And do it for the freedom's sake without coercion, violence, killing? (4)

I confess that what I have had to say provides no concrete, specific image of the future. I have blurred some existing distinctions --formal education and the real world and teacher and pupil, for example --but have offered almost nothing in the way of new models. It is the best I can do. Perhaps the only professional teachers will be those who arrange learning situations (find television tapes, help plan excursions, bring teachers and pupils together, counsel, guide, advise, etc.) for others. Perhaps science educators will become the men and women who take on the unclaimed and incredibly difficult task of working at the interface of science and society . . . of assuming those social and ethical responsibilities for scientific and technological developments that no one in our contemporary society has yet accepted. Perhaps the full-time involvement with knowledge, understanding and skill-development--getting, sharing, teaching, and learning--will become an integrated, life-long activity in which we all participate.

I regret that I do not have the blue-prints of that future world to share with you. Perhaps I will know better in five, ten, or fifty years. Today, my efforts are in a different direction. My daily acts are motivated by simplistic notions of caring about what happens to people . . . and so, for example, I vote against a college honors convocation because I don't believe learning is a matter of competition.

My long-term efforts are directed at trying to understand better what our future priorities and intentions might be in a world of cooperation and love instead of one of competition and hate. I look for guidance and inspiration and understanding in this search not to the mainstream of our society or our culture. Those of us grown up and now imbedded in the establishment or the system are unlikely to understand what a radical future might be like. Those of us who were trained to respect power, who were taught how to fight for it, and who can not now rid ourselves of the thirst for it are not likely to see what a future without power might be like. And so a Ford and a Kennedy, a Kissinger and a Richardson, a Peale and a Graham, a Skinner and a Bruner, and all the elder statemen of science education have little to say to me.

I rely, instead, on those who are and have been on the fringes of our society to know and understand what human relationships might be that they never have been in our culture. Reformation and transformation of society--whether the setting be Roman Palestine, Sixteenth Century Germany, or Colonial America--have commonly grown and developed in outcast and rebellious sub-cultures. I doubt that the new American revolution will occur in any other way.

And so I look to the writings from the Gay liberation movement, from feminists, from the Black movement, from dissident scientists and engineers, and from all those other freaks whom society has condemned to its outer fringes. For in assigning these misfits to a cultural limbo--out of sight and out of power--society has provided them with a perspective and an understanding which only rarely comes to those of us who have it made under the traditional rules of society. And while our professional associations and scholarly journals devote themselves to efforts at improving, correcting, adjusting, and modifying the system in which we now operate, writers and thinkers from the fringes are developing totally new concepts of what we might expect of social change, what our hopes for education should be, and what, indeed, it means to be human in a post-technological, post-scarcity society.

For my own part, I am increasingly excited and encouraged by the first tentative visions of what a more egalitarian form of scientific research and science education in the future might be,[23] of the new models for a more human and more humane personal development which might be investigated,[24] of the alternative kinds of personal and social interrelationships and groupings which are being tested,[25] and of the implications all of this might have for the way we encourage and assist human learning.[26]

We wonder about the future. We cannot know what *to* build until we learn what we *can* build. We cannot yet define structure and function because we are lacking in imagination. Humans have always relied on dreams to show them the highest, the brightest, and the best that might be. Today, some of our most hopeful dreams of the past have faded; others are now outmoded or inadequate. This is the time to dream again, to search for the most hopeful, the most human that we can be. There will be ample opportunities for bricks and mortar, for wood and nails. Today, we need to see the sky and the stars; we need to hope and to dream.

> I'll tell you something more revolutionary than politics, more radical than the Left. *Support*. Just that, support. Sounds dotty, doesn't it? Silly, very apolitical, but it's the biggest change I can think of . . . giving another person total support. Never balking, just hanging in, believing in them while they get it together. The most you can offer another human being. It changes things from the very bottom (4).

FOOTNOTES

1. Probably the best history of science education in the United States available at this time is Paul Hurd's "A Critical Analysis of the Trends in Secondary School Science Teaching from 1895 - 1948," Unpublished doctoral dissertation, Stanford University, 1949. See also David E. Newton, "Personalistic Conceptions of Education and the Teaching of Science in American Secondary School," Unpublished doctoral dissertation, Harvard University, 1971.

2. A number of writers have described the cultural revolution which seems to be taking place in American society. See, for example, P. A. Sorokin, The Crisis of Our Age (New York: E. P. Dutton, 1944), Ch. 1; Kenneth E. Boulding, The Meaning of the 20th Century (New York: Harper Colophon Books, 1964); Margaret Mead, Culture and Commitment: A Study of the Generation Gap (Garden City, New York: Natural History Press and Doubleday and Company, Inc., 1970); Theodore Roszak, The Making of a Counter Culture (Garden City, New York: Anchor Books and Doubleday and Company, Inc., 1969); Daniel Bell, The Coming of Post-Industrial Society (New York: Basic Books, Inc., 1973); and Robert L. Heilbroner, An Inquiry into the Human Prospect (New York: W. W. Norton, 1974).

3. Although the previous discussion is couched in fairly global terms, one should obviously be cautious in talking about social and cultural issues in the U. S., Afghanistan, and Japan in the same breath. I suspect that there are important, universal features of the "cultural revolution." In this brief chapter, however, I will speak of only the culture I know, mid-twentieth century U. S. society.

4. A superb analysis of the nature of science using this general analogy of a "game" is Garvin McCain and Erwin M. Segal, The Game of Science (Belmont, California: Brooks/Cole Publishing Company, 1969).

5. The sociology of science is probably understood poorly by science educators and, sometimes by scientists themselves. Basic reading in this subject might start with Bernard Barber and Walter Hirsch, The Sociology of Science (New York: The Free Press, 1962).

6. At least I believe that scientists think that the structure of science is intended to keep its truths pure and value-free. Some would argue that value-free research is a naive and unrealistic concept and that there are many more biases within science than we usually admit. Much of the work of the Scientists and Engineers for Social and Political Action (SESPA), through their journal, Science for the People, has been directed toward pointing out these hidden values and hidden biases. See, for example, John Stewart, "Science: Political and Personal," in Science for the People, VI (5), September, 1974, pp. 6-7.

7. This case study, admittedly in the realm of science fiction, is regularly used in a course on science and society which I teach. If the example seems bizarre, one should remember that it is the structural elements of the case rather than its specific content that are important. For the full case, and others like it, see David E. Newton, *Science and Society* (Boston: Holbrook Press, 1974), Part Three.

8. One of the few examples which come to mind of a scientist's withholding the results of his research is the case of Norbert Wiener. See his article, "A Scientist Rebels," *Atlantic Monthly*, January, 1947, p. 46.

9. The recent international conference on recombinant DNA molecules at Asilomar, California, provided an interesting, unique, and possibly precedent-setting approach to problems involving the social and ethical implications of scientific research. For a report of that conference and later, related events, see Nicholas Wade, "Genetics: Conference Sets Strict Controls to Replace Moratorium," *Science*, CLXXXVII (14 March, 1975), pp. 931-935 and Nicholas Wade, "Recombinant DHN: NIH Sets Strict Rules to Launch New Technology," *Science*, CXC (19 December, 1975), pp. 1175-1179.

10. There are now a vast number of examples of the problems of federal regulatory agencies. See, for example, Robert J. Bazell, "Cyclamates: House Report Charges Administrative Alchemy at HEW," *Science*, CLXX (October, 1970), pp. 419-420; Morton Mintz, "FDA and Panalba: A Conflict of Commercial, Therapeutic Goals?" *Science*, CLKV (August, 1969), pp. 875-881; Joseph Sax, "A Little Sturm and Drang at Hunting Creek," *Esquire*, (February, 1971), pp. 84-88; Nicholas Wade, "DES: A Case Study of Regulatory Abdiction," *Science*, CLXXVII (July, 1972), pp. 335-337. A more complete list of similar articles may be found in Newton, op.cit., pp. 283-285.

11. The contrast between this interpretation and what I believe is happening in almost all science classrooms is stark and frightening. It is a subject to which I will return later in this chapter.

12. A number of good books are now available on the relationship of science, industry, and government, especially since the Second World War. See, for example, J. Stefan Dupre and Sanford A. Lakoff, *Science and the Nation* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962). A review of science education journals from the period 1955 to about 1960 provides a particularly interesting and illuminating picture of the way government and industry leaders saw the relationship of science, industry, government and education. See, as just one of many examples, Gustav Egloff, "The Impact of Industry on Science," *School Science and Mathematics*, LIV (February, 1964), p. 106.

13. See previous footnote on federal regulatory agencies.

14. Lynn White, Jr., "The Historical Roots of Our Ecological Crisis," *Science*, CLV (March, 1967), pp. 1203-1207.

15. I offer no claim for originality in this analysis of schools. A number of writers have already discussed the implications of the hidden curriculum in schools. See, for example, Jerry Farber, The Student as Nigger (New York: Pocket Books, 1969), Edgar Z. Friedenberg, Coming of Age in America (New York: Vintage Books, 1965) especially Ch.4, Robert Dreeban, On What Is Learned in School (Reading, Massachusetts: Addison-Wesley Publishing Company, 1968), Miriam Wasserman, Demystifying School (New York: Praeger Publishers, 1974).

16. I offer this term to describe the process which sometimes seems to go on in schools when--in contrast to learning--students leave the classroom apparently knowing less than when they went in.

17. Friedenberg, op. cit., p. 170.

18. New versions of educational utopias arrive each year. Basic references for me have included Neil Postman and Charles Weingartner, Teaching as a Subversive Activity (New York: Delacorte Press, 1969); George P. Leonard, Education and Ecstasy (New York: Delacorte Press, 1968); Herbert Thelen, Education and the Human Quest (New York: Harper and Row, Publishers, 1960); and Donald Stotler, The Self-Learning Society (Portland, Oregon: Northwest Library, Inc., 1970).

19. Earl C. Kelley, In Defense of Youth (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962), p. 124.

20. Probably the most dramatic exceptions to this statement come from the work of the Progressive Education Association. Philosophies expressed in the PEA's Reorganizing Secondary Education and Science in General Education were and are, to the best of my knowledge, unique in U. S. educational writings. They would serve in my judgment, as exceptional guides to educational practice today.

21. Two useful references on the factory school model of education are Charles J. Brauner, American Educational Theory (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1964) and Raymond E. Callahan, Education and the Cult of Efficiency (Chicago: The University of Chicago Press, 1962).

22. Described in Donald Wm. Cox, The City as a Schoolhouse (Valley Forge, Pennsylvania: Judson Press, 1972).

23. Stephen J. Risch, "Towards a Gay Analysis of Science and Education," in Louie Crew (ed.), The Gay Academic (Palm Springs, California: ETC Publications, in press).

24. For example, Adrienne J. Smith, "Fearful Past, Hopeful Future: Coming Out as Mental Health" and Barbara Love, "A Case for Lesbians as Role Model for Healthy Adult Women," papers presented at the American Psychological Association convention, Chicago, Illinois, 1975.

25. An interesting and optimistic view of the commune movement in the United States, for example, is found in John Rothchild, "American Communes: Voluntary Maoism," *The Washington Monthly*, June, 1975, pp. 16-23.

26. See, for example, Ron Schreiber, "Giving a Gay Course," *College English*, XXXVI (November 1974), pp. 316-323. By far the most useful utopian overview of a "new" society which I know of is Shulamith Firestone, *The Dialectic of Sex: The Case for Feminist Revolution*. New York: Bantam Books, 1970, Conclusion, pp. 203-242.

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5. Mumford, Lewis. *The Condition of Man*. New York: Harcourt, Brace, and Company, 1944.

6. Sampson, Ronald V. *The Psychology of Power*. New York: Vintage Books, 1965.

7. Stockholder at the annual meeting of the General Electric Corporation, as quoted in *The Free Paper*, April 23, 1975.

8. Taylor, Walter P. "The Biology Teacher's Responsibility to Society," *American Biology Teacher*, 14:64, March, 1952.

CHAPTER 8

THE PAST, PRESENT AND FUTURE OF SCIENCE EDUCATION

BEFORE, DURING AND AFTER THE YEAR OF THE GOLDEN-FLEECED MACOS

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The opportunity to prepare this closing chapter for the 1976 Yearbook is one of two significant professional events that occurred to me during the past year. The other event is one that I hope will permit me to offer a perspective on science education that I know I could not have offered a year ago. This was my year with the National Science Foundation's Division of Science Education where I served as a Program Manager responsible for planning and evaluation.

While the Foundation has made a considerable impact in science education in the past with its support of curriculum development efforts, inservice and preservice programs for teachers of science as well as fellowship programs that a number of us have benefitted from, never in the history of science education have there been more questions asked and concerns raised about the Foundation's role than in 1975. In a microcosm, the Foundation's problems during the past year reflect similar problems within all of science education.

The authors of the earlier chapters noted the present difficulties and also provided an historical and conceptual rationale for the crossroads that we find outselves in today. We have not been immune to the recent barbs, criticism, and laughter that many educators and scientists have heard. The National Assessment of Educational Progress (NAEP) results noting the lowering science test scores of students, the numerous textbook controversies, the increased level of hostility from parents about the content and instructional approaches in our science classes in elementary and secondary schools, are all evidence that times are changing more quickly than the acceleration to which we have become accustomed.

Science educators in general and members of AETS specifically have fought long and hard to be accepted leaders in not one but two professions -- science and education. We have done well in a few short years. At the time of our greatest growth, the problems of the late 60's and 70's seemed distant -- as if they never would exist. School budget constraints would never become such that portions of science programs would be eliminated; teacher militancy would never come to the point where striking colleagues would close down schools for weeks; parents would always view science and science education in the same light -- positively. After all, Congressmen would never stoop to questioning the titles of research projects nor would they ever consider demanding that they approve of individual research projects that would be supported by the prestigious National Science Foundation. It would just never happen that vocal opponents could force the elimination within school districts of a social science course that was designed to aid children to focus on their values.

But these things and others did happen. The significance of these happenings, regardless of their causes, has great importance to us in science education. Our methods, means and motives have been and are now being questioned. We are members of that group that must develop and implement efforts that will permit the present and future science teachers of our country to function more and more effectively with students. What we plan and how we implement our efforts will be scrutinized more carefully in the next several years than anything we have done to this point.

The chapters that preceded this one focused on historical and conceptual perspectives for today's decisions and those that we will make in the future. I feel that the chapters have done much to crystallize the problems as well as analyze their probable causes. In addition, there have been a number of reflections about possible solutions to the problems. I feel that it is my role, as a synthesizer, to look at some of the issues that are identified in several of the chapters as well as present some reflections of my own.

SCIENCE EDUCATION -- CRISIS IN OUR DEVELOPMENT

> Like people and plants, organizations have a life cycle. They have a green and supple youth, a time of flourishing strength, and a gnarled old age . . . . An organization may go from youth to old age in two to three decades or it may last for centuries (3:20).

Jim Barufaldi, Dave Newton and others in the initial chapters of this yearbook have given considerable thought and effort in describing the past growth and future projections of science education. In reading those chapters I could not help but reflect on an article that has made a considerable impact on my professional life. In 1967, Gordon Lippitt and Warren Schmidt wrote their "Crises in a Developing Organization" paper for the Harvard Business Review (8). In this paper, Lippitt and Schmidt reflect on six crucial crises and response patterns that a developing organization faces on the road to viability. In a way, the history, present and future of AETS and science education reflects a similar situation. We are not a business in the usual sense of the word; however, there are a number of similarities that strike me in viewing the situation that we as science educators find ourselves in today.

The table in Figure 1 is a translation of Lippitt and Schmidt's paradigm as it may fit our profession and its growth.

FIGURE 1

Developmental Stage	Concern	Key Issues	Consequences of Failure to Meet Concern
BIRTH	1. Creating an organization	What do we risk?	Frustration and inaction.
	2. Surviving	What do we give up?	Death of organized science education efforts toward the adequate education of science teachers.
YOUTH	3. Gaining stability	How do we organize?	Reactive; crisis management in reaching our goals. Opportunism rather than self-directing attitudes and policies.
	4. Gaining reputation and pride	How do we review and evaluate?	Difficulty in getting good personnel and clients. Over-aggressiveness; distorted image building.
MATURITY	5. Achieving uniqueness & adaptability	Should we change? How?	Unnecessary defensiveness and competitive attitudes. Loss of creative personnel.
	6. Contributing to society	Should we share? How?	Lack of respect and appreciation by public.

It is my feeling that we have reached level 4 on the above chart. In fact, I see us groping in level four. Our groping in the next months and years will determine if we actually become a mature profession, one that is truly unique and adaptable. I'll come back to this point again and again, but first let me describe how I see us from the vantage point of 1976, looking back at how we took our first several steps.

Creating Our Organization

Concern	Key Issues	Consequences of Failure to Meet Concern
1. Creating an organization	What do we risk?	Frustration and inaction

By organization, of course, I am speaking of science education, not just AETS. Jim Barufaldi alluded earlier to the impetus that occurred in the 50's and I don't think we can overestimate this impetus — it is ample evidence of what can happen in education given the right set of circumstances. Jim refers to the 50's as the dawn of contemporary science education and I agree. I see the 50's as the time of the birth of what we now know as science education. I say this hoping that those of you who were the mainstays of science education prior to that time will forgive me for being a naive youngster.

The White House Conference in 1955, the concerns for the need for science and technologic manpower to win the Cold War, the expressions of disenchantment with the way science was being taught in public schools and colleges, the lingering concerns about the low performance of Army inductees on achievement tests all pointed the way. However, the social climate reflecting the general distrust of the role of government in the affairs of state and local elements was there as well. Until this time there had been little in the form of targeted Federal support for specific education programs. However, the motivation for increased quantity and quality in national science education outputs provided both the impetus and the opportunity for Federal support. The basic assumption was that only through what Averch, et al., call exogenous shocks (impetus from external sources) could schools adequately accelerate their normal evolutionary patterns toward excellence (1).

Through what channel would the government act? Earlier informational materials provided to teachers by the Atomic Energy Commission made only a very limited impact on science classes. Something else would have to be done. But who could deal with these problems? Schools were not producing the needed scientists and mathematicians. Few high school graduates viewed these careers with seriousness. Furthermore, in the opinion of many, schools and teachers were not adequately preparing even those students who chose science as a career. In essence, there was a perceived wide gap between the school experience of students studying science and the frontiers of science. Those scientists on the frontiers were considered the ones who could narrow this gap, both through instructing teachers of science and through insuring scientifically correct and up-to-date science curricula for schools.

This involvement of scientists in the education of teachers and students of science was applauded by most people. In fact, the reactions of most citizens toward the scientist of the 50's was quite positive. As Nisbet (10) notes:

> In all the polls and surveys of prestige in American society, the scientists and scholars ranked high. In fact, in the period beginning with the end of World War II, the scientist-scholar became the real hero in American society, joining in a circle that had, with rarest exceptions, been limited to politicians, generals, explorers, artists and sports illuminaries (4).

Support from the government started rather meagerly. In its third year of existence, 1953, the National Science Foundation took the rather bold move of providing funds for "Summer Institutes" to assist college teachers in learning "more about recent developments in their own and allied fields" (16:53).

The year 1954 saw the support of three college-teacher summer institutes and one institute for high school teachers of mathematics at The University of Washington. This latter four week program was funded with 10,000 dollars. The years 1955 and 1956 saw an increase in these institutes. The development of Academic Year Institutes began in 1956. These training programs allowed classroom teachers to study with college-based research scientists, increasing the teachers' skills, knowledge and competence in science.

The rush was on. The Foundation went into the budget hearings for Fiscal 1957 requesting $850,000 for support of Summer Institutes and another $3,000,000 for development and support of Academic Year Institutes. In regard to this latter request, Representative Albert Thomas of Texas noted to the Director of the Foundation:

> Certainly you ought to pursue this new program that you started for the training . . . courses for your high school instructors . . . . If you can use $9,000,000 or $10,000,000, we are certainly prepared to give it to you. You are really striking at something worthwhile (7:188).

Some 96 Summer Institutes and 16 Academic Year Institutes were supported in 1957.

The other prong of support, the development of scientifically correct and up-to-date curricula, began during this same time period. Research scientists like Jerrold Zacharias, James Killian, Arnold Grobman and others assumed roles on writing teams that developed curricula for secondary science and mathematics classrooms.

Science and the scientists were in.

These early efforts were predicated on a rather simple assumption: that there was a linear model that could be followed to cause positive changes in school science education. The assumption was that if correct and up-to-date curricula were (1) developed, they would be (2) disseminated and (3) implemented into classrooms throughout the nation. The assumption seemed valid, especially in the light of R & D models that were working in science and science-related industries. In industry, those innovations which worked were indeed disseminated and used.

I believe that the failure of this assumption caused the creation of our profession. The developed curriculum materials were indeed correct and innovative. But, for the most part, these early developments worked best with more capable students. Similarly, the curricula seemed to work best with those teachers adequately prepared to use the materials. Getting the physics teacher of the day to teach PSSC called for more than the simple addition of texts, films and laboratory materials. One teacher was quoted as saying, "How can I teach this (PSSC) and physics too?"

Similar less-than-successes were seen in the Academic Year (AYI) and Summer Institutes. The linear assumption behind AYI and Summer Institutes was that increasing the skills and knowledge of high school teachers would, by itself, improve science education at the local level. The changed teacher, complete with his added repertoire of skills often found himself in an awkward situation when he returned back home. The old texts were still there. The old organization structures were still there -- getting a double period lab for the teaching of physics was difficult to swing. Getting the necessary laboratory materials was next to impossible.

The failure of these two interrelated linear assumptions provided the need for someone who was both a scientist and an educator -- one who had a background in science and could insure accuracy and relevancy of science content; this same person, however, had to have a valid perspective of education that would permit the acceptance of and insure the use of valid instructional materials and techniques in the real world of the classroom. We, as science educators, emerged with quite a mission.

Surviving

	Concern	Key Issues	Consequences of Failure to Meet Concern
2.	Surviving	What do we give up?	Death of organized science education efforts toward the adequate education of science teachers.

Being born with great expectations, as our profession was, provides opportunities as well as responsibilities. Dave Butts focused on many of the responsibilities in Chapter 5. He noted how our earlier preparation programs were designed to insure our credibility with science and academic colleges. This was no mean feat, since, for generations before this time, Colleges of Education and Colleges of Arts and Sciences seldom recognized the existence of each other. In addition, science educators were taking over more of the responsibilities of translating science to the teacher. Summer Institutes and Academic Year Institutes were being taught more and more by the science educator -- the person who could translate science into the classroom and thus more effectively help the teacher. These same institutes started providing more in science education offerings. Many of the science education courses dealt with how to implement the newly developed science curricula into school settings as well as how to inject new science into existing science courses in the high schools. NASA got into the act by providing a large vehicle (complete with demonstration equipment) that was driven from campus to campus demonstrating how space science could be incorporated into science classes.

At this same time, curriculum writing efforts became the product of teams of scientists, classroom teachers and college-based science educators. Different versions of some curricula were developed with different content emphases. Materials were pilot tried in classrooms and the results of these trials were used to make changes in second and third drafts. This first attempt at what Ken Komoski of EPIE refers to as learner verification provided a unique opportunity for the science educator who was not only surviving, but also in demand.

In Chapter 2, Gene Craven pointed to economic situations and their impact in determining who will go into education as a career. This same impetus provided the backdrop in which a number of us found ourselves in the early 60's. Science education provided a respectable compromise between science and education. While we may not have been research scientists, we could still find ourselves in the aura of science. We could also keep our contact with schools, other teachers, and students. And there was a demand. I am certain that more than a few of us remember a NARST meeting in 1965 when a chairman of a department of science education in a southern state rose to announce that he had three assistant professor positions at salaries $4-5,000 per year greater than anyone had heard before. The bidding war was on and it felt nice to be wanted.

Gaining Stability

Concern	Key Issues	Consequences of Failure to Meet Concern
3. Gaining stability	How do we organize?	Reactive; crisis management in reaching our goals. Opportunism rather than self-directing attitudes and policies.

By the mid-sixties it appeared that science education would not only survive but would also flourish. As a benchmark of this, one need only look at the development of research in science education. Much of the research that Mary Budd Rowe described in Chapter 6 can trace its roots back to the research movement in science education in the 60's. Dissertations were expected to be experimental, in keeping with the Ph.D. research expectations of the science communities. Descriptive, developmental and survey research efforts were considered as mere "educationese" and not suitable or worthy of science educators.

An organization, to exist by itself, needs to have a separate set of guidelines and an area which it can call its own. The educational researcher reports his findings in education journals. The scientist reports his results in science journals. If science education were to be a discipline, it needed to stake its claim as well. The first issue of the Journal of Research in Science Teaching arrived in 1963. Since its arrival, JRST and a modified Science Education have become the bastions of science education research results.

Another benchmark of the arrival of science education was the appearance of the 1960 yearbook of the National Society for the Study of Education. Rethinking Science Education (13) announced some startling ideas about science education -- ideas that seemed unthinkable or at least unprintable in the last NSSE yearbook devoted exclusively to science education that was published only 13 years before.

New alliances were also formed. In our attempt to create new paradigms for viewing education as a science, psychological theories and psychologists became well known to all. Bruner, Piaget, Gagné and others became the saints of science education, their theories used to explain existing phenomena and to shape future efforts.

One of these efforts was the beginning of curriculum development efforts and teacher education activities for science teachers in elementary and junior high schools. The elementary school science "readers" became the inquiry-discovery process science activities of science classes, thanks to the leadership of scientists, psychologists, and, of course, the forward-looking science educators.

Another measure of stability was shown in the emergence of the so-called Science Education Center -- a tightly or loosely knit collection of faculty, staff, and students that focused together on neither education nor science but, indeed, on science education. The Center formed the core around which the science educator-to-be planned and developed his preparation program. Typically the faculty of the Science Education Center called upon the services of colleagues in science departments to provide students with the expected background in the content of science. Education colleagues were called upon to offer courses and experiences in curriculum, instruction, research and the like. But the faculty of the Science Education Center also offered unique science education courses, often with SCI ED labels. This latter development was no mean feat at some universities.

With Science Education Centers there was also an emergence of the Director -- someone whose background in science typically far outshadowed his education background. This person could, indeed, talk with scientists in other departments. Science Educators with names like Hurd, Novak, Lee, Collette, and a host of others had had positions in Botany, Geology, Physics, Genetics and Chemistry a decade earlier.

Gaining Reputation and Pride

Concern	Key Issues	Consequences of Failure to Meet Concern
4. Gaining reputation and pride	How do we review and evaluate?	Difficulty in getting good personnel and clients. Over-aggressiveness; distorted image building.

I mentioned earlier that I think we are still in this level of development. An organization with a reputation sets goals that others follow; the organization is a trend-maker, not always a trend-follower. Ten years ago, it appeared that science education was on the brink of being a trendmaker; there was a set of curriculum and instructional strategies that were accepted by most science educators. Publishers made attempts to emulate the results of PSSC, CHEMS, CBA and BSCS. While commercial texts were being influenced by developments in science education, similar developments in teacher education efforts also existed. Those inservice courses were valued that were designed to teach teachers to use higher order questions, be patient and practice wait time and use set inductions that would lead to discovery learning in the classroom. School districts bragged about their up-to-date and modern science programs.

Things have changed, however. Think about the changes that have occurred in textbooks in the past 20 years, with 1965 right in the middle. Twenty years ago, most physics texts were emphasizing the understanding of technology -- how a light bulb works, the kinds of levers and their operation, etc. In this exceedingly short time (by educational standards) we have seen;

Science education as facts -- "Make them learn those things that they need to know."

Science education as concepts -- "They have to understand the rudiments, not the unrelated facts."

Science education as principles -- "They're bigger rudiments."

Science education as problem-solving -- "Teach them to solve the problems."

Science education as discovery -- "Only those things that they discover will be meaningful."

Science education as inquiry -- "We can't figure out the difference between problem-solving and discovery so we'll call it inquiry (except in Chicago where it is enquiry)."

Science education as process -- "Teach students the ways of science."

Science education as attitudes -- "If they only knew and appreciated what science education was like, they would learn."

Science education for interpersonal skills -- "If kids learn science they will feel better about themselves and others."

Science education for ecology -- "Only the science teacher can help students see the need for ecology."

Science education to teach kids to read -- "Reading is it; if you've got to teach science at least make certain the kids can read."

An interesting exercise is to explore the hidden storage closets of some innovative schools. This exercise is akin to a geologic or anthropologic dig; the findings provide a capsulized historical perspective of the changes in school curricula that have occurred over the past twenty years.

There have been significant reasons for this seemingly constant changing in schools and education in general. Historical perspective provides ample evidence that more than just science education has changed in the past twenty years. Our profession was born at a time when there was an elitist attitude toward schools and education. Education was a way to get ahead for the student, if he could excel. The function of education, indeed, was to identify those students who could excel. Students showing strength in science (remember science fairs?) were to be nurtured with the best curricula, the best instructional materials and the best prepared teachers.

During the mid-60's, education was viewed in a different light. The role of education was to insure equal opportunities for the nation. It was through the school that the equality of individuals was to be insured. Reading, mathematics, the basics were in. Other things were in also, but . . . (FLES supporters recall it well; at this time foreign languages in the elementary schools started to wane and with this waning the need for the foreign language educator -- an educator whose profession got a similar impetus to the one that ours received in the 50's.)

When the movement toward the development of science education curriculum began in the late 50's the thrust was obvious -- our charge as scientists, educators and science educators was to aid in the improvement of scientific and technical manpower. However, by the middle of the 1960's, with other significant changes, the goals of science education were changing. More and more Ph.D.'s in physics and mathematics were not finding positions. The aerospace industry that looked endless five years before was cutting back. The need for increased numbers of professional scientists was fading.

A conscious switch in preparation programs followed these changes. Science education for literacy was emphasized. Basic reading and mathematics skills were reconsidered. We were placed in a position of having to justify "hands-on" inquiry science programs for the elementary school by showing how well they aided inner-city kids to read and perform mathematical calculations. In the latter 60's a movement arose that was aimed toward providing the individual with more self-knowledge and control of his environment.

Planning within education during times of changes such as these is always haphazard. Curriculum development efforts, those supported by the National Science Foundation and also by private sources, attempted to keep up with the times. Group inquiry efforts were developed around BSCS. Other curricula emphasizing group process skills, creativity, understanding the environment, flowed as quickly as publishers could print. However, the time it takes to develop and actuate an effort of these magnitudes always kept science resources behind the times.

We seemed to be living, breathing examples of the Heisenberg Uncertainty Principle. If we acted, the thrust changed.

The ability that we have demonstrated to modify our approaches with changing times has been both a blessing and a plague. Obviously, our responses in light of changing societal pressures have kept us afloat years after colleagues in other discipline-education efforts have seen their barges go under.

We are now having to justify the results of these efforts, efforts that in many cases were not the result of our wishes. Our failure to provide answers to many of the questions that are being raised today may be because we have not had the luxury of standing still long enough to figure out what we are all about. I can't see this luxury in the near future, yet the questions are not going to go away.

A VIEW AT/FROM THE PRESENT

Please accept the fact that I am not trying to play the combined roles of Holt, Kozol, and Silberman. I certainly do not see myself as a prophet of doom. I recognize that during the past twenty years we, as science educators, have been able to accomplish more than our share as well as to catalyze additional constructive efforts throughout all of education. I am proud of our accomplishments; however, my pride is tempered with the belief that we can and should improve upon what we have done.

In this section I would like to explore some of the common threads that I see running through the earlier chapters; threads that culminate with unsolved problems or issues that gnaw at each of us. The threads that I identify include: (a) The Everything to Everyone Syndrome; (b) The Knee Jerk, Gut-Feeling Syndrome; (c) Institutional Memory; and (d) Responsiveness.

The Everything to Everyone Syndrome

I can't imagine any member of AETS viewing our profession as being in a period of expansion. Money is tight; an indication of this can be seen simply by looking at the Science Education Directorate budget of the National Science Foundation. In the past ten years sizable amounts of money has been siphoned from Summer Institute/ Academic Year Institutes to other reduced forms of teacher education efforts, culminating with a zero budget for Fiscal Year 1976. The anticipated budget for FY '77, even if Congress permits money for precollege education efforts, is only a small fraction of that in the past.

Non-NSF funding has also dried up to a great degree. NDEA funded fellowships that many of us benefitted from in the late 50's and early 60's were spent to a large extent on science and mathematics education. Later ESEA and ESAA funding that followed certainly did not approach the level of effort for science and mathematics education reflected in NDEA efforts. Current NIE and OE budgets support little in the form of science/mathematics education.

In our growth period there was money available. Our efforts were numerous and a number of these efforts were highly successful. However, there were some difficulties as well. In a growth period, organizations are always permitted the luxury of exploration, error, and sometimes waste. In a growth period it is expected that the organization will be able, through planning and trial and error, to identify those areas it will focus on in later stages of development.

However, in a period such as we find ourselves now, there is little room for waste. Our time for exploration in an infinite number of directions is past. An immediate key goal for AETS and all of science education must be the identification of persuasive priorities. We can no longer afford the luxury of being everything to everyone.

This thread is seen in many of the preceding chapters. It really is a two-layered problem affecting both the individual science educator and science education as an organization.

Individually, the problem is one that has given me as much trouble as any in my career. I am expected to be a generalist at the same time I am a specialist. As a science educator, I am expected to be skillful in teaching, research, supervision and curriculum development. I am also expected to be an untiring writer and consultant (K - 12, of course) in all areas of science. As those of you who know me can attest, I fall considerably short of these expectations.

Dave Butts, in Chapter 5, put his finger on the difficulty when he described the genesis and evolution of the doctoral programs in which many of us studied. We were expected to have a broad, yet specialized, in-depth understanding of science. Yet the scientists that we studied under were not just biologists or botanists, they studied excised root cells. The educators that we worked with were not just educators but curriculum specialists, supervisors of K-3 science or teachers of gifted students.

I recall walking down the hall with a friend of mine, Ralph Cain, after I had completed the defense of my dissertation. Ralph was an old hand -- he had completed his degree two years earlier. I asked him, "When does someone show me how to do all of the things that I am expected to be able to do?" I was pleased to have finished my program and I felt that I was competent in some areas; however, I was considerably less confident about other skills I thought I was expected to have. Ralph never has answered my question.

Dave soothed my concerns somewhat when he described how existing programs are reflecting a shift toward specialization. His chapter, coupled with Mary Budd Rowe's comments about research efforts and the necessary preparation to complete these research efforts, aided me as well.

Each of the earlier chapters on inservice efforts, preservice efforts, supervision, and research identify unique professional skills for different roles. Obviously, it is important that each of us demonstrates a familiarity with all areas of science education. However, we need the luxury of being able to specialize if we are to make personal impact. Perhaps the preparation programs that Dave described will permit a degree of generalization yet specialization that will be required of science educators in the future if the promises described in the other chapters will bear fruit.

The second layer of the Everything to Everyone syndrome is more global in nature. Our history is marked with conscious and unconscious bending in the wind of public and professional opinions. This bending, as I mentioned earlier, has probably kept us afloat as an organization. However, the bending has left us, other educators, and the public in doubt of our real mission.

Is the role of science in the classroom that exemplified by PSSC and other earlier-developed science efforts? Should science teachers be expected to assist students in the understanding of the basic rudiments of science? Or instead should science provide an opportunity for all students to become more aware of themselves and their environment -- goals exemplified in some of the more recent curriculum development efforts? While there is room for philosophic discussions among these variations and the infinite number of options in-between, we as a profession are going to have to come to grips with our role quickly. If we don't face this issue soon, we may not be everything to everyone but will wind up being nothing.

The Knee-Jerk, Gut-Feeling Syndrome

One of the problems associated with running any kind of education effort is that there are few people outside of education who have taken the time and effort to focus carefully on the intricacies of program planning and operation. The public sector now talks about accountability and cost-effectiveness in education. They look for evidence that schools are worth the taxes that are spent and all they see are lowering test scores and perceive that the only way to solve the problems of the schools is by forcing teachers to teach the basics so their children at least can "make change for a $5 bill."[1]

This same kind of evidence is sought by Congress to justify the expenditures. The Department of Defense can come to Congress with a budget of over 100 billion dollars. The Department can point to numbers of weapons, planes and tanks that will be purchased. The identified weapons have specifications that identify their strengths and describe in detail their capacities to help us defend our country.

On the national level as well as on the local level, there is little that we as educators can do to justify with numbers our goals, roles and outcomes. An example is seen when the National Science Foundation appears before Congress for budget discussions. At these times the Foundation can note that funds awarded through its Directorate for Science Education permitted X teachers in Y states to be affected by its programs. Z curricula can be identified as being developed with Foundation support. In addition, Q faculty members were awarded fellowships. Congress retorts, "What were the results of these efforts?" -- the same question that is being echoed throughout all states and throughout all school districts. Unfortunately, the evidence that is piling up reflects "no significant differences" when comparing programs at the local level.[2]

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1. This statement is taken from context, but is one piece of evidence noted by columnist James J. Kilpatrick (6).

2. For a more detailed description of these findings see Averch et al. (1).

Regardless of the statistics behind these findings or the reasons for the statistics, many of us still have gut feelings that there have been positive outcomes as the result of science education efforts in the past 20 years.

When under attack from some outside source, a group can do one of three things: ignore the attackers and hope they will go away; submit to the attacker; or counterattack. The history of education is replete with the reactions that we as educators have given -- typically it is (1) an ignoring, believing that the outside attackers really don't understand education, followed by (2) a counterattack with alternative data and epithets at the attackers for tramping on sacred ground. I am going to define this reaction of ignoring followed by counterattack as a knee-jerk. It may be ingrained in each of us to a point where we can't stop it, just as it is impossible to stop the response of the knee cap to a well-placed tap.

I submit two recent examples:

The first example of this syndrome occurred after the release of NAEP data showing that between the years 1969 and 1973, there was a decline in student achievement and science knowledge for 9, 13 and 17 year olds. At the time of the release of the data, few of us were prepared to accept the fact that there had been such a decline. We as a nation had just spent a huge amount of money and effort getting science education to a point of national pride. Our personal reputations as science educators were also at stake if these data reflected a correct trend. Most of us stated that the results were obviously in error; in essence we ignored the data because of an alternative gut feeling.

After this initial denial it was obvious that the results were not going to go away. Press coverage and questions raised by parents and later by Congress made that clear. So we counterattacked by stating reasons for these findings:

1. The findings were only artifacts of the weird methods used by NAEP.

2. The exercises used in the effort were weak; they were only memorization in nature. Our programs emphasize process.

3. The cause must be TV. Kids watch too much TV.

4. Students really don't care anymore.

5. "I could have predicted the results; schools are really changing; no one teaches real science anymore."

If you were like me, you used a number of these reasons and more. If you are like me, you are still bewildered about the entire situation both with the NAEP results and the diminished SAT, ACT, and other scores.[3]

I'll come back to the NAEP example, but first look at a second "knee-jerk" reaction. This second one I have lived with for some eight months -- NSF's fight with Congress and its criticisms.

Actually, the fight has been two-pronged in nature. One set of Congressmen, led chiefly by William Proxmire (Wisconsin) focused on the use of tax monies funneled through Federal agencies like NSF to support "scientific" studies of, among other things, hitchhiking, primate teeth, the African climate during the last ice age, and the social behavior of the Alaskan Brown bear. Not all of the efforts in Proxmire's "month's biggest boondoggle" or his "Golden Fleece" awards were supported by the Foundation; however, the Foundation serves as a focus for science considerations at the national level and this focus was a clear target for Proxmire and other critics.

A second prong of the attack was led by Congressman John Conlan (Arizona) and was aimed first at Man, A Course of Study (MACOS), a social science program whose development was supported by the Foundation during the 1960's. The program was designed to be an introduction to anthropology for middle school youngsters and to provide local school districts with an alternative to their existing social science offerings. From the point of view of many educators, MACOS is a technically excellent, relevant and significant improvement over many existing social science offerings; a large number of school districts adopted the program during the late 60's and early 70's.

Obviously, not all parents of students studying MACOS were happy and they had an open ear with Conlan. During the early part of 1975 Conlan, in committee sessions and later on the House floor, attacked the program for "turning children against their parents using shock techniques and other 'psychological devices' . . . causing children to reject the values, beliefs, religions, and national loyalties of their parents" (14).

The rhetoric of the House and the Senate did not stop with "Golden Fleeces" and shouts against MACOS. From initial questions in these areas evolved attempts to insure Congress' screening of all research grants for "silliness" and further attempts to insure that the Foundation's budget did not include funds for assisting local school districts in learning about and implementing NSF-supported curricula, MACOS or other. The implementation efforts supported by the Foundation were the last vestiges of Summer Institutes and Academic Year Institutes designed to provide inservice help for teachers.

Ignoring such attacks was a leisure that few of us as science educators could afford. For one thing, a growing number of Congressmen were hearing from the public their "wasted" tax monies. To many of us the "Golden Fleeces" were cheap shots on Proxmire's part. The fact that he was able to get away with the shots reflected serious concerns on the part of Congress and the public to keep governmental (in this case NSF) spending from getting out of hand. Governmental spending for science as far back as can be remembered has always been for the practical, the tangible: millions for the moon or cancer, but little if any for non-understood "science."

Congressmen were also hearing from parents concerning federal role in education, changing curriculum emphases and MACOS. This news clipping appeared in a local newspaper in one of the wealthiest counties in the United States during this time:

> Resolution on Education
>
> The Maryland Federation of Republican Women recently passed the following resolution expressing its concern over current trends in education. The resolution follows:
>
> WHEREAS, we, the members of the Maryland Federation of Republican Women are disturbed at current trends in education -- specifically certain curriculums which use psychology to shape the thinking of students, and the general teaching of concepts instead of facts, and
>
> WHEREAS these trends have resulted in cases in which children have been alienated from the values of their parents and turned against traditions of our culture, and
>
> WHEREAS this has been a factor in lower reading levels leading to the necessity of simplifying college textbooks and a reduction in achievement levels of Maryland students, and[4]
>
> WHEREAS Federal money is being used to fund such curriculums which are written by theorists and behavioral scientists who are attempting to resocialize our children, and
>
> WHEREAS such Federal funds are being used to train change agents to accomplish these goals, without knowledge or consent.
>
> BE IT THEREFORE RESOLVED that we, the members of the Maryland Federation of Republican Women urged all Maryland PTA's to investigate those programs and take action at the individual school level, and
>
> BE IT FURTHER RESOLVED that we urge our State Senators and Delegates to sponsor and-or support legislation that will allow parents to have access to curriculum;
>
> BE IT FURTHER RESOLVED that the President, Vice President and our Senators and Representatives use their offices as public servants to investigate, explore and halt these practices;
>
> BE IT FURTHER RESOLVED that a copy of this resolution be sent to all Maryland PTA's advisory committees and local school boards, and to all Republican elected officials at the State and Federal level with a request for a response indicating what action they will take in this regard (12).

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[4] Underscoring not in original text.

At this same time, Congressmen were hearing and seeing other knee jerks from the science and science education communities. In more letters to editors of professional magazines than I care to remember, Congressmen both individually and collectively were assailed as "stupid," unknowledgeable, and incapable of judging both scientific research as well as totally ignorant of decision making at the local school level.

For fifteen years science education efforts had attempted to generate a "scientifically literate" set of adults; now we as scientists and science educators were accusing Congressmen, of all people, of stupidity and not understanding science. These attacks were not very helpful, needless to say. Many of them generated knee-jerk reactions from the Congressmen.

Such situations where strongly held "gut feelings" exist on each side are difficult to compromise. Data do help. It was interesting during this time to read the Congressional Record and to hear of pro-NSF Congressmen reading the titles of research studies completed by Nobel laureates and others. These "silly" titles described studies that led to the discovery of relevant cures and findings. The only study title that I did not hear was that original study that led to the breakthrough that made human hair transplants possible. I felt certain that this would have swayed Senator Proxmire. The Foundation also prepared a rather lengthy document that described each of the "boondoggle" studies in detail and related why they were important. This same memo noted, incidentally, that very few of the "Golden Fleece" studies were supported by the Foundation.

With hearings held, letters read, and data gathered, an amendment in the House that would have required Congressional approval of individual science research efforts was defeated by a very slim margin (215-196). Scientists breathed a collective sigh of relief. We science educators were not as fortunate, however. Monies for implementation efforts were removed.

There are a number of reasons for the loss. The preliminary reason was that we were unable to change the minds of Congressmen. Those Congressmen in the middle swayed the other way. We were not able to muster the forces nor the data to convince Congress otherwise. Bill Mayer in an editorial in the October 1975 American Biology Teacher refers to this as the "9.2 million dollar silence." His point was stated:

> Congress -- a political animal -- responds to its constituency. Congressmen pay close attention to the wishes of their constituents. When either a feeble response or none at all is engendered by a given issue, the Congressman understandingly feels that it is either of no interest to his constituents or, at very least, that there is no opposition to it (9:440).

According to Mayer, our silence cost 9.2 million dollars last year.

Maybe you do not totally agree with the statements that Mayer makes. Maybe there are other reasons for the cut. However, I feel that Congress desires more and more data on which to base its final decisions as to whether or not the federal government should be in education at all. Consider the statement from the Congressional Record that effectively eliminated funding last year:

> Since the Foundation is currently developing a number of courses . . . which have never been reviewed by the Committee in terms of their national need, the Committee has included no funds for the implementation of courses in 1976. This will give the Foundation time to prepare the necessary data and to fully inform the Congress and the public of its intentions and the basis on which it has determined the pressing need for such course material. It will also give the Congress time to fully evaluate the impact of federal involvement in this field and arrive at effective public policy guidelines for the development and implementation of such materials.[5]

Someone needs to prepare the necessary answers for questions such as those that have been raised. We have demonstrated in past efforts that we can collectively answer such questions. I remember how the Southwestern Regional AETS, under the leadership of Wendell Spreadbury, joined forces and through a massive letter-writing campaign influenced, to a large extent, Congressional passage of a bill that saved much of the Big Thicket in Texas.

I also have seen in the past months how Congressmen have requested more and more information from the Foundation as a result of inquiries that AETS members and other science educators have made with respect to the support of science education efforts.

We can also work together to focus on other problems. An example of this latter effort is the cooperative effort between NSTA and NAEP in focusing on the declining test score problem (16). We need data that each side can at least agree upon, even if they can't agree on the interpretations.

There are a number of elements identified in earlier chapters that are candidates for the knee-jerk syndrome. The reactions that we as professionals make to these problems, may, in the long run, be even more critical than those we made to the two issues that I identified.

The first candidate is the changing decision-making process and procedures within the teaching profession. Initial knee-jerks to teacher unions' reactions to supervision, inservice efforts and certification programs have not been totally positive. We as members of AETS must work cooperatively with classroom-based teacher educators in planning for future efforts.

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[5] Underscoring not in original text.

A second sub-candidate was described in detail in Gene Craven's chapter. CBTE or competency-based teacher education probably evokes the most easily identifiable knee jerks that can be seen. There seems to be no middle road on this subject — people are either totally for or totally against CBTE. We as an organization need to be careful to avoid blanket acceptance or rejection of this concept without careful study that involves a study of both our needs and those of our clients.

A few other knee-jerk candidates are identified in the next sections.

Institutional Memory

In a presentation that I heard Jonathan Wirt of the Rand Corporation make recently, he used the term institutional memory to describe how people within organizations remember those things they find useful and forget those things that are not considered useful. I think the term has several facets that can be identified in our organization.

My first example of this syndrome I will place in the form of a question: "Do we really believe our research findings?" Mary Budd Rowe has presented one of the most coherent and complete descriptions of the state of the art in science education research that I have seen. Coupled with the AETS-supported Review of Research on Teacher Behavior completed in 1973 by Balzer, Evans and Blosser (2), Mary's chapter provides a wealth of ammunition for the continued development or refinement of science education efforts through the nation.

My concern is that we use the data that we have. Although research into teacher education is in its infancy, we know substantially more about teaching now than we did twenty years ago. Yet, I have seen little use made of our increased knowledge. The incessant need that we have had to innovate has caused us to ignore the results and opinions of others, simply because they are someone else's. I am thinking here of the number of person-hours that went into the development of some of the PSTEP efforts for the training of undergraduates. How many findings of these efforts are used, let alone known, by most of us who have spent our equally valuable time in building programmatic efforts? Similarly, I am amazed at how well we ignore the suggestions of panels such as those that produced the publications, Preservice Science Education of Elementary School Teachers: Guidelines, Standards, and Recommendations for Research and Development (11) and Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics (4).

If we don't accept the suggestion of peers in the development of pilot efforts, we certainly will not believe the research data that follow the study of such efforts.

Another effort that we can make to break this institutional memory syndrome is to continue our cooperative relationships with other teacher educators. I have the feeling that in the past we have treated preservice science education efforts as something separate from other forms of teacher education. There is much to be gained from the cooperative working with others outside the field of science education. Dave Newton makes the point in his chapter on the future of science education: We need to see, more and more, the chemistry teacher as a teacher who just happens to have a specific content background in chemistry.

Responsiveness

In reading earlier chapters I see ample evidence of our ability as a profession to respond to the needs of our clients -- an important factor in the growth of a developing organization. I see the building of collaborative relationships between education and science, the development of scientifically correct and educationally sound instructional materials and the immense improvement of preservice and inservice teacher education efforts, all as proof that we have positively influenced education. These solutions were aimed at a definite problem -- the perceived need for a more scientifically literate population.

Our responses to today's problems are being questioned. In fact, many of the problems are laid at our feet. No one can doubt that the problems of today's schools are massive. Violence in the classroom, serious questions about the roles that all members of the school should play, concerns from parents about content and processes in the classrooms, the increasing numbers of students who report being "turned off," budgeting problems, salary disputes, strikes, lowering test scores -- the list is endless. And there are few among us who propose the same solutions that we used effectively in the 50's and 60's to solve the problems of those days. To many people, a quote that I heard recently from a math supervisor in Ohio would be an echo: "We have become better and more efficient at teaching things that should not have been taught in the first place."

Earlier, I mentioned that I have serious questions about whether we have actually believed our research findings. I noted that there was frightful little evidence that we have used the research results in designing curricula or focusing on instructional strategies. In truth, we have done research and development when we should have been doing research, then development.

Part of this problem has been a result of the response to be doing more research, rather than first considering how the research effort fits into the totality of science education, its goals and needs. Such a failure could not help but produce the monumental stacks of highly unrelated research efforts, much of which fits into the category of "tinkling" research efforts alluded to in Mary Budd Rowe's chapter.

Recently, I was reading some descriptions of research that I was involved with in 1964. The following quote struck a responsive chord as I was reading:

> We must then be centrally concerned with what the child learns, the conditions under which different individuals achieve this learning most rapidly, and the evidence each child gives of having achieved the objectives of science education.

The quote was attributed to Watson and Cooley (1959), however, this writer did not give an additional bibliographic reference.

It seems to me that if we continue this "tinkling" research we will be no closer to an answer to this problem 50 years from now than we are today. And the problem is not going to go away.

Obviously, it will take massive research efforts to focus on the questions that we have in education. However, if we are to continue growing as a profession we must start by identifying those areas. This research will be costly, both fiscally and personally. We have demonstrated that we have the research skills; we have the motive and the motivation. I'm convinced that we can find the money. Making up our minds to start may be the hardest thing to do.

The second hardest thing may be working out the cooperative arrangements necessary to complete the work. Cooperation is one of those words that sounds so good and yet is so hard to attain -- especially when your entire preparation program has been based on competition rather than cooperation. If you were like me, you were expected to be competitive throughout your entire career. Grades were very important to you as a student. Promotions come to you as a result of being better than someone else. Even your publications must be accepted in refereed, competitive journals. Similarly, co-authored papers are considered as less valuable than single-authored works. You must make it on your own as a professional -- and making it means being better than someone else. This competitive spirit is difficult to break. As an example of this, I submit the following story.

When I attended graduate school, I was told by my advisor that I should take earth science courses. Frankly, I was not even remotely interested in taking geology. I wanted to take more and more chemistry, so I, on my own, took advanced physical chemistry and biochemistry courses. No one ever caught my oversight and I completed my degree without the required geology.

However, now I am interested in geology; an interest catalyzed primarily by my daughter's questions. In addition, NSF offers these nice courses through George Washington University. Designed primarily for secretarial and nonprofessional administrative staff members, the courses are offered free of charge. So, I signed up for this beginning geology class when an opening appeared. I thoroughly enjoyed the class.

But now the problem. I found myself wanting an A. I was sweating for an A. I was desperate for an A. I started the course wanting information and ended the course grabbing for a grade. When I took the final exam I had the same sweaty hands that I had in graduate school and the same jitters that I had when I went to talk to my dean about my promotion.

Now this may not worry you, but it worries me. I am convinced that we need to do something in our preparation programs that teaches the next generation of science educators how to cooperate toward mutual goals. It seems to me that the problems that we have today and the problems that will be generated in the near future call for cooperative efforts. We better be prepared to use them. In the spirit of the Bicentennial either we hang together or we hang separately. (Ouch!)

AETS/SCIENCE EDUCATION — WHAT NOW?

There is enough in the first seven chapters of this book to keep us thinking and planning for several years. Unfortunately, we do not have the time to slowly digest the evidence. In our profession, this is a luxury we have never had.

I mentioned in my description of our professional growth that I feel we are somewhere in Level 4 as identified by Lippitt and Schmidt (8). Unless we are content to remain mired at Level 4 or, worse yet, lose ground, the next years must be productive ones, both in planning and doing. This decision to move or not to move is one that has its risks. Some of the risks were noted earlier but I think are worth the effort to explore again:

FIGURE 2

Developmental Stage		Concern	Key Issues	Consequences of Failure to Meet Concern
BIRTH	1.	Creating an organization	What do we risk?	Frustration and inaction.
	2.	Surviving	What do we give up?	Death of organized science education efforts toward the adequate education of science teachers.
YOUTH	3.	Gaining Stability	How do we organize?	Reactive; crisis management in reaching our goals Opportunism rather than self-directing attitudes and policies.
	4.	Gaining reputation and pride	How do we review and evaluate?	Difficulty in getting good personnel and clients. Over-aggressiveness; distorted image building.
MATURITY	5.	Achieving uniqueness & adaptability	Should we change? How?	Unnecessary defensiveness and competitive attitudes. Loss of creative personnel.
	6.	Contributing to society	Should we share? How?	Lack of respect and appreciation by public.

In many ways the right-hand side of the chart reflects many of the concerns that I felt as I read the earlier chapters of this volume. There are numerous examples of crisis management and overreactiveness on our part. Authors used these as targets to describe possible solutions. These targets were especially evident to me in Bob Ziegler's and Bill McIlwaine's discussion of the need for adequate supervision in the time of change and in Alan Voelker's discussion of inservice efforts. I felt an underlying plea for quality recruitment from Gene Craven and Dave Butts. Mary Budd Rowe's pleas for interrelated research based on common paradigms translated to me our need for self-directing efforts. I heard Mary and others calling for science educators to deal with research and development efforts from a position of system ownership rather than individual proprietorship.

It appears to me that one of the reasons that science education has stalled at Level 4 is because we have been a very loosely connected enterprise. AETS, NARST, CESI, NSTA, CS^3, AAPT, NABT, etc., all exist as independent agencies with few, if any, well defined parameters. It is obvious that the skills within these organizations are outstanding; yet we often seem to get in the way of each other. This is not to say that there has been antagonism or hostility between the groups; heck, most of us belong to more than three of the groups. What I guess is missing is the synergy that should exist when professionals with different specific skills and areas of expertise all focus on the same area -- science education.

Perhaps this focus on getting the synergistic relationship could be a first step. I am reminded of a set of assumptions about leadership and cooperative efforts that a friend of mine, Dick Ford, has prepared:

a. Most people, most of the time, want to do the best job possible.
b. People need to be taken seriously.
c. Leadership can and should be a shared function.
d. People who are closest to the action are the best sources for information.
e. People need to be involved in planning and decisions that will impact directly on their activities.
f. When there is trust there is validity in data; when there is low trust there is low validity in data.
g. In the absence of shared objectives there can be no accountability, only justification.[6]

To me this list describes some excellent guidelines that should be found in any cooperative effort. As you explore the list with respect to your own life space, I am certain you can identify areas where we in science education have excelled and other areas where we could improve.

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[6] Presented with the permission of Richard Ford, President of Richard Ford, Associated, Syracuse, New York.

Two immediate needs that I see from the list are (c) the need for leadership sharing and (e) our need to focus on important goals and objectives. One of the reasons why much of our research is filled with "no significant differences" may be because we have not been able to agree on what goals and objectives are valuable for science education. If we cannot agree on our goals and objectives, we certainly cannot be accountable to ourselves.

A second level of accountability is also alluded to in Dick's (g) statement. Science educators cannot forget that we are representatives of a subsystem within all of education and that the movements that we make must be influenced by the goals and objectives of all of education, just as our changes will affect others. If we are to be accountable for our part of the education of teachers and science and, ultimately, the students of science, we must identify our roles within the context of all of education. A failure to do so will insure years more of justification rather than accountability.

In relation to (c) I am concerned about our recruiting and keeping creative personnel within science education; a failure here is noted by Lippett and Schmidt as a consequence if we do not continue to grow as a profession. Are we making available the opportunities for shared leadership in science education? Do those science education graduates who initially focus on a career in teacher preparation feel that they own part of the system?

I am reminded of an anology about the evolution of discipline that our editor, Gene Hall, tells about Ponds and Frogs that reflects on the loss of personnel. In pond-like organizations there are all kinds of flora and fauna, a truly differentiated staffing pattern. There are leaders ("Big Frogs") and there are followers ("Beavers" and "Super Stars"). More than likely many of the Super Stars have some skills that the leader frogs perhaps may lack. If the Super Stars are not given the chance to be involved in the planning of pond activities, they very easily can move to another pond where their skills can be more appreciated and they can make an impact on this other pond's directions. Similarly to ponds, organizations can become stagnant if this leadership is not shared, thus producing some creative solutions to algae growth problems.

The bottom line of the story is that there is an immense amount of creative potential in all of science education. Supervisors, classroom teachers, teacher educators, researchers, all of us have roles that must be tapped to insure that the directions we select for the future are realistic, relevant, and viable.

If this sharing is not encouraged by AETS and other organizations, the next generations of Big Frogs are going to place their efforts on achieving more rewarding personal goals, or change ponds. This loss of creative personnel will certainly cause the death of organized science education.

To me, the past few years have seen a pause, not a stop, to the development of science education. The next years will see major changes, changes hopefully catalyzed by AETS.

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